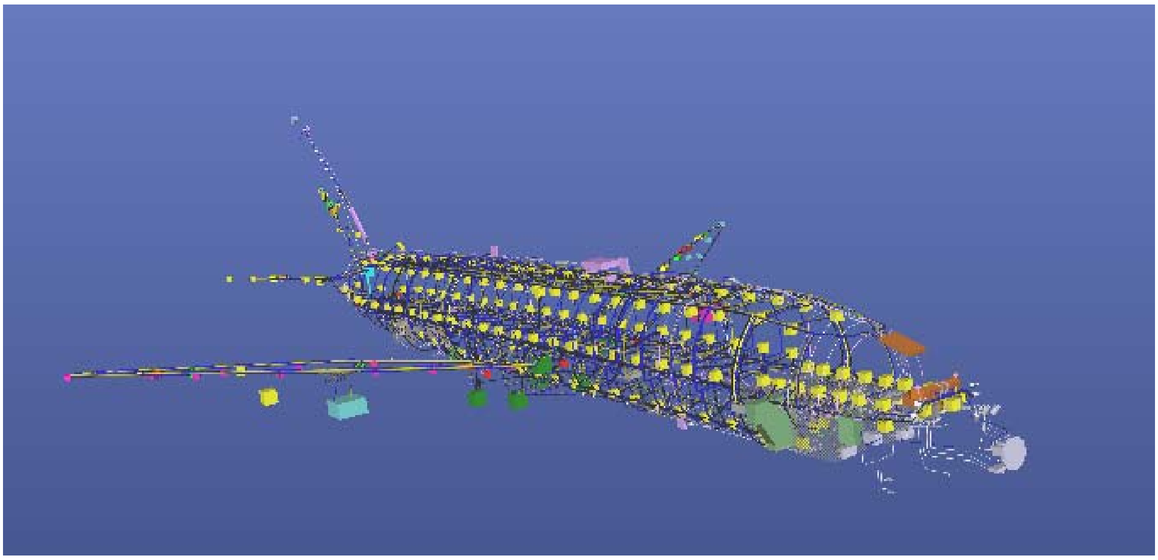

Improvement in the Electric Sizing Process for Aircraft applications

Acquisition and improvement of the electric diagrams checking methods, and research on a new process of aircraft assembly, regarding electric installation performances.

Master of Science Thesis in Electric Power Engineering

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Göteborg, Sweden, 2009

Electric Sizing Process For Aircraft Applications.

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ACKNOWLEDGEMENT

This master thesis was an extremely interesting and very rewarding experience. The opportunity I got to do it through an internship with ALTRAN and AIRBUS had been a non-negligible experience as regarding social relationships as regarding the development of my technical skills. I would like to particularly thank the whole team members of the electric installation department for their cheerfulness and to have facilitated my integration in these companies; and particularly Nicolas PHILIPPE and Michel BAREILLE my two supervisors for their very award help.

I also would like to thank my supervisor at Chalmers, Torbjörn THIRINGER, for his incommensurable patience for all the difficult administrative issues he helped me to go through, and his nice support all along the master thesis time.

And finally I would like to thank my family for their support during the time I spend in Sweden, because without their help, this wonderful adventure would have not been possible.

ABSTRACT

This master thesis focused on the electric installation for aicrafts applications. The AIRBUS' tools have been used, as for example FD-Q-Check tool or IRIS, to performed the results. Regarding the FD Quality Check Activity, improvements have been provided to this activity, by this master thesis in order to improve the quality of the electric diagrams for aircraft, but also to reduce the sizing data (length, weight of cables...)

The seond part of this master thesis is a research work which compares two processus of assembly of fuselage. Analyse and investigation of two scenario (full barrel and french baguette) have been performed.

During this master thesis, improvements of electric diagrams have been provided, some are quantitative some are only qualitative. Some suggestions, and new verifications cannot be measured, but one exemple presented allowed to save13 kg of wires.

For the research activity, regarding aicraft assembly process, it has been shown that the new scenario could be interesting regarding electric installation, because it could save around 400 connectors, which represent a weight of 80 kg, apart from the economical saving made by the large reduction of connectors.

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1 PREFACE

ALTRAN was created in 1982, ALTRAN is today one of the European leader in innovation consulting. ALTRAN assists its clients at every stage of the innovation cycle in three business lines: in technology and innovation consulting (accounting for nearly half the turnover), in organization and information systems consulting (a third of the turnover) and also in strategy and management consulting.

In 2008, the Group's turnover reached 1.650 million euros. ALTRAN represents more that 18.500 employees in over 20 countries.

This thesis has been done in cooperation with ALTRAN SUD OUEST (ALTRAN SOUTH WEST); branch of ALTRAN which has been created in Toulouse in 1985 and represents over 1000 engineers in Midi-Pyrénées and Aquitaine (two regions in the south west of France).

Engineers of ALTRAN S.O. work in many different fields, some examples are given below:

- Supply chain management: ALTRAN procures advices for strategy and organization in order to improve performances.
- Cockpit & Avionics: Engineers can act for aircraft manufacturers, operators and avionics suppliers, but also for airport certification (safety, efficiency, environmental strategy etc)
- ALTRAN Configuration Management: this department helps companies to get others accreditations, ISO 9001, ISO 14001 etc …
- Tests & *Means tests:* ALTRAN SO can also provide test benches to make simulation and tests for any equipment.

For all these activities, ALTRAN works on behalf of most of the biggest engineering groups e.g. AIRBUS, CONTINETAL, ROCKWELL, DASSAULT Aviation, CNES, TURBOMECA, VALEO, etc …

This thesis has been done on behalf of AIRBUS, as a subcontractor for the Electric Installations Team.

2 INTRODUCTION

The first flight of the A380 constituted for Airbus a technical prowess, but the European aircraft manufacturer cannot therefore be satisfied and stop its efforts. Indeed far new challenges await it, in particular in the electric fields. Electric architecture must in a near future evolve to adapt two major changes, which are: the **more electric aircraft** and the **more composite aircraft** (i.e. incorporating more carbon). Indeed, several types of equipment have to change from being operated by hydraulic or pneumatic energy to being operated by electric energy. In addition composite materials generalization must appear on the entire fuselage and not-only on the wing and tail cone anymore. Actually, the goal is to get a lighter aircraft and in that way a lower fuel consumption, i.e. most cost-effective for the companies and more environmental friendly.

It is in this context that the master thesis has been conducted, and has been performed through an internship for a subcontractor of AIBUS: ALTRAN. The master thesis was divided into two missions, one is about electric diagrams verification, and the second was a research work regarding a new assembly process for aircrafts.

The purpose of the first activity was, after getting familiar with the check, and the validation of diagrams using AIRBUS tools, to suggest improvements in order to deliver better inputs data for the sizing team. This activity mainly focused on the quality, the reliability of the electric diagrams, and also on weight saving.

The purpose of the research work was to compare a new process of assembly for aircraft to the current baseline. The comparison of the different scenarios had to be done using electric mock-ups, in order to compare the advantages of each solution, and also to try to optimize the most interesting scenario, here again, in term of weight saving.

3 PRESENTATION OF AIRBUS

3.1 AIRBUS IN BRIEF

AIRBUS SAS is a European aircraft manufacturer created by the consortium of several companies. Nowadays, it is one of the two biggest manufacturers in the world (direct concurrent of the American Boeing).
The main dates, relevant of the activity of this company are:

- 1957: Creation of Sud Aviation (south aviation)
- 1969: First flight of Concorde
- 1972: First flight of A300 B2 (270 seats)
- 2000: Birth of EADS (European Aeronautic in Defense and Space) with the creation of aeronautic department "AIRBUS SAS"
- 1994: first flight of A300-600ST. Figure 1 a photo of this Aircraft is presented.
- 2003: withdrawal of Concorde
- 2000-2005: Beginning of different programs A380/A400M/A350. The A400M is presented in figure 2.
- 2005: First flight of A380: biggest civil aircraft Finally, Figure 3 is a photo of the Airbus A380.
- 2013: First flight of 350 and A400M
- 2017: First flight of the A30X

Figure 1: A300-600ST


Figure 2: A400M

Figure 3: A380

In July 2003, three companies (Aérospatiale Matra SA, Construcciones Aeronáuticas SA et Daimler Chrysler Aerospace AG) from Aeronautics and space fields created EADS. AIRBUS belongs at 100% at EADS

EADS produces a very large range of equipments for aircrafts, helicopters (for civil or military utilization) satellites, space transport etc. AIRBUS is today the number two of aeronautic industry in the world behind BOEING

In Figure 4, it can be seen that with almost 57.000 employees AIRBUS is the main subsidiary of EADS. AIRBUS generated in 2008 a turnover of 25 billions of Euros which represents 64 % of the turnover of EADS

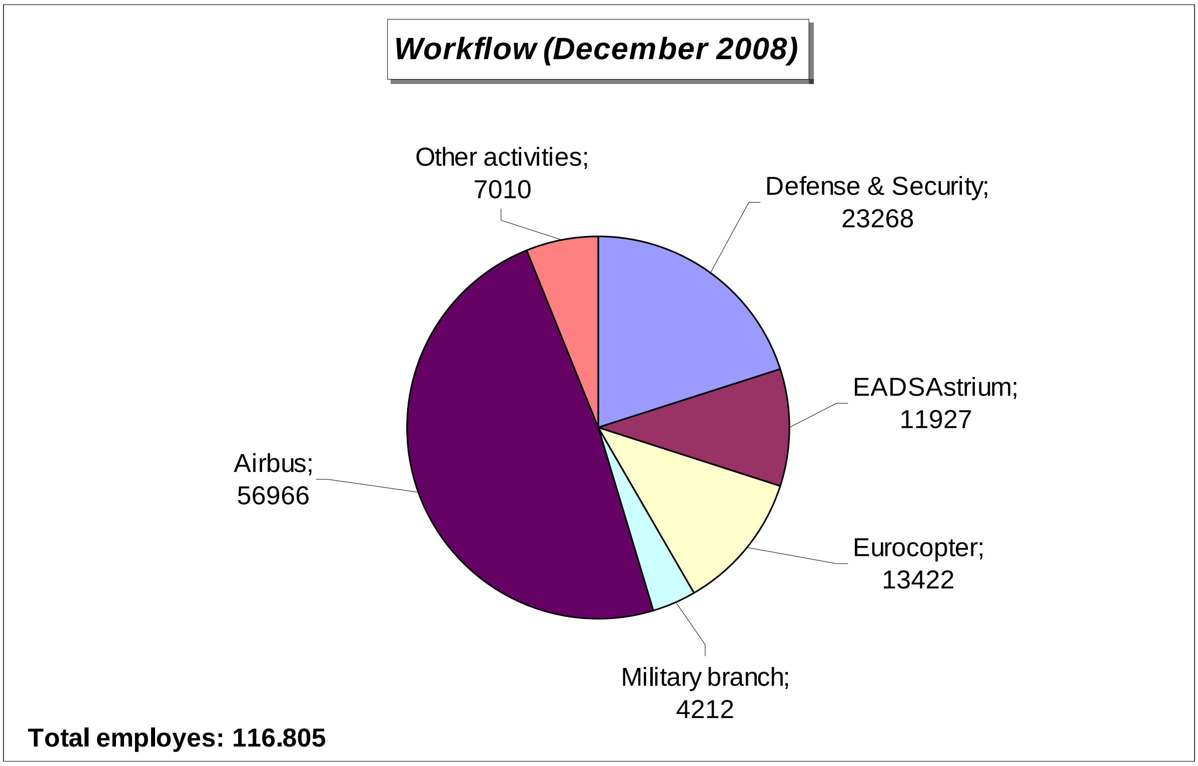


Figure 4 : Workflow of EADS (12/2008)

Since it has been created, AIRBUS received 8873 orders from 296 different customers and realized more than 5200 deliveries of aircrafts.

3.2 AIRBUS' ORGANIZATION

AIRBUS employs around 57 000 people, mainly divided over four countries. Around 23 000 people are employed in France (Méaulte, St Nazaire, Nantes and Toulouse), around 3 000 in Spain (Getafe, Illescas and Puerto Real), 10 000 people in the United Kingdom (Broughton and Filton), and 21 000 people work in Germany (Stade, Hambourg, Nordenham, Brême, Varel and Laupheim)

Generally, an aircraft is composed by seven parts: the nose fuselage, the front fuselage, the central fuselage, the back fuselage, the wing, the cone tail and the engines. That configuration is presented in Figure 5

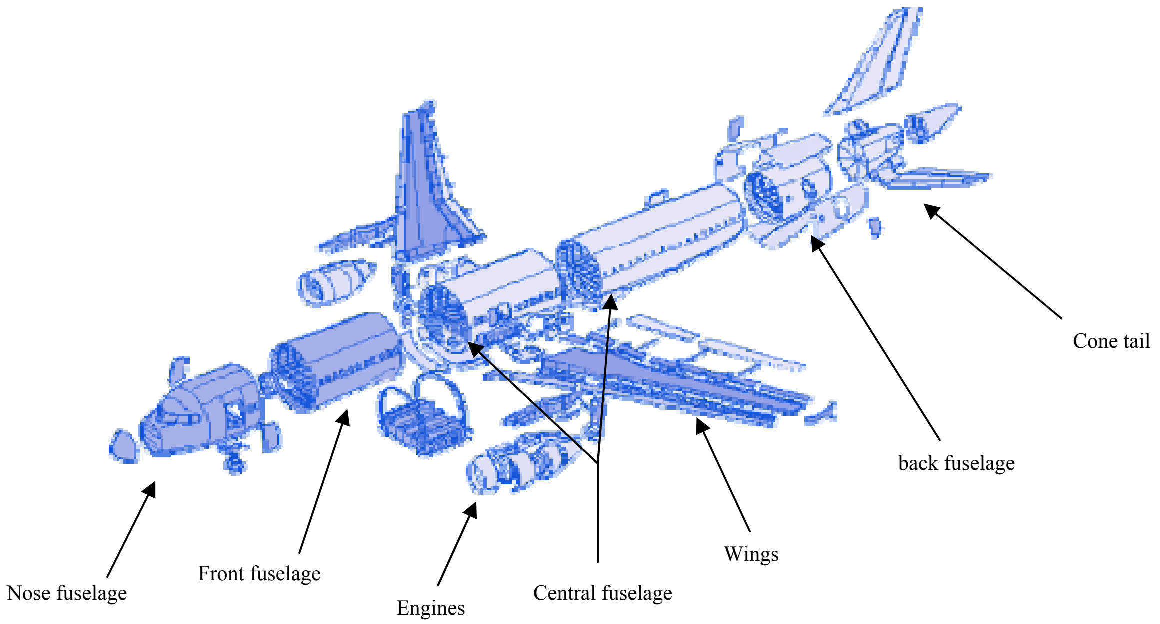


Figure 5: Assembly schema

The size and the number of pieces of the central fuselage depend of the range of the plane. The central fuselage of small planes (e.g. A320) is composed by only one part. For the engines, two configurations exist; they can be under the wings or at the back of the plane. The cone tail is constituted by the horizontal tails (2) and the vertical tail

The different parts of a plane are made in different countries. On speaks of NatCos (National Companies). The different pieces are made all over Europe, as it is show in Figure 6. And the final Assembly Line is in Toulouse or in Hamburg.

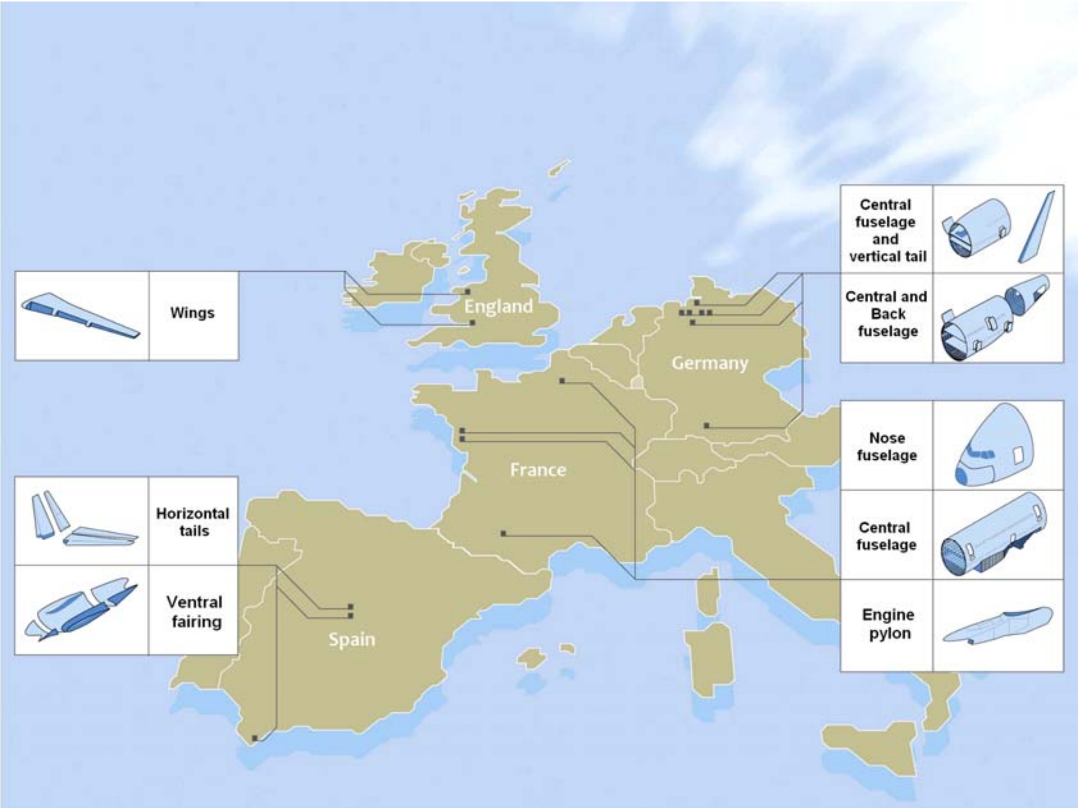


Figure 6: Repartition of the production by NatCo

The factory of Toulouse and Hamburg make the last assembly and the last tests before delivering the aircraft to the AIRBUS' customers.

AIRBUS' customers are airlines companies (58,5 % of orders) and also private persons that order private jet (1,5% of orders). Airlines companies can be divided into two groups, airlines companies that use theirs aircrafts, and companies that buy aircrafts to rent them to others companies.

3.3 AIRBUS PRODUCTS

Currently AIRBUS makes a range of 13 models divided in 3 main families that can be seen in Figure 7.

A320 Family: (4 aircrafts)
It is the most common family, and the most sold in the world. It represents 70% of the sold realized by AIRBUS. An A320 has a capacity included between 107 and 220 passengers, for a trip distance of 6000 km maximum. The production of this model is around 35 aircraft per month!

A330-A340-A350 family: (8 aircrafts)
The A340 is the first aircraft with a crossbeam in carbon (introduction of new materials). The A350 will be made using 60% of new materials, and most of them will be composite materials. These

aircrafts have a capacity included between 253 and 475 passengers, for a trip distance of 16 000 km maximum.

A380 family (1 aircraft)
It is the biggest civil plane, with for the first time a double bridge over the whole aircraft. It may welcome between 525 and 853 people, for a trip distance of 15.200 km maximum. It is the first civil aircraft including 25% of composite materials in its structure.

The two others families are separated from others due to their specific utilizations:
A300-600ST
This aircraft is a Super Transporters. It is used only for freight transport. It is also named Beluga due to its strange shape. This plane can flight with a charge of 153.900 kg.

A400M
The A400M is an aircraft make by the military branch of AIRBUS. It is only dedicated for military activities, as troupes transport or as a tanker for others plans.

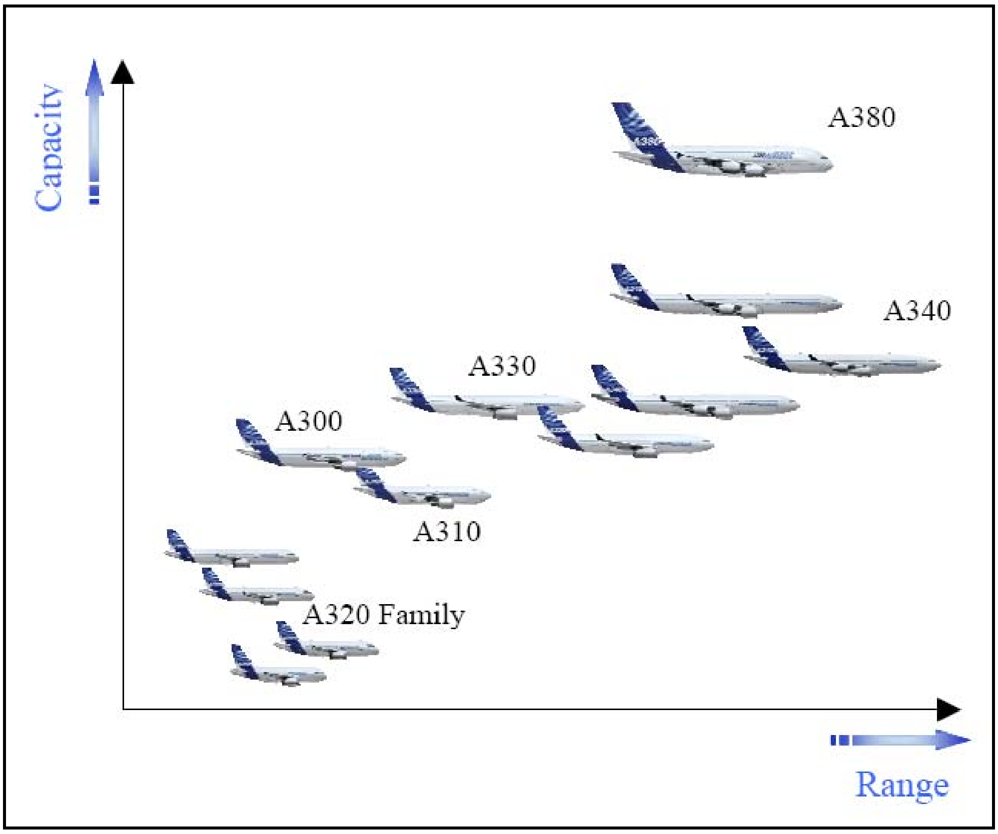


Figure 7: Evolution of A/C capacity.

Figure 7 represents the evolution of the capacity of the different aircrafts in function of type of aircraft.

3.4 THE ELECTRIC INSTALLATION DEPARTMENT

At the origins of aeronautics, electricity was only used for auxiliary functions (light, start-up, etc.). All the important equipments worked using mechanical, hydraulic or pneumatic technology and process. Electricity was not considered as a safety source of energy. Then, due to the advent of civil aviation and the radio-navigation the electricity has been hugely developed. Nowadays, electricity on board is more and more used, for very different utilizations - one speaks about more electrical aircraft. Most of the equipments use electricity, even on board instruments and all types of instrumentations, control systems, … Electricity development is always in progress, and this suggests that its utilization will be further intensified. These evolutions focus on security, comfort improvement but also on weight reduction. Obviously on more electric aircrafts, the components dedicated for electricity utilizations represent a bigger and bigger weight. This weight has to be limited as much as possible for environmental and economical reasons.

The Electric Sizing Team is responsible for sizing operations concerning the Electrical System Network. Indeed, they have to extract all the dimensions of electrical harnesses (diameters, lengths, types of protections etc.) designed by all the system designers; and they suggest improvement or correction to do in the electric installation in order to reduce the weight of the electric equipments, preserving the safety.

A system designer makes the diagrams of an ATA or a Sub-ATA (Air Transport Association). The utilization of ATA and Sub-ATA is very useful to divide all the electric system in an aircraft. The list of the mains ATA can be consulted in APPENDIX 1

The system designers make diagrams with different issues, different maturities. There are also different levels of advancement: Block Diagram (BD), Functional Diagram (FD), Extended Principle Diagram (EPD) and Wiring Diagram (WD); and each diagram has also a maturity (A, B, or C). That represents a very long process between the first block diagram and the final wiring diagram that will be implemented on an aircraft. That process is schematically explain in Figure 8

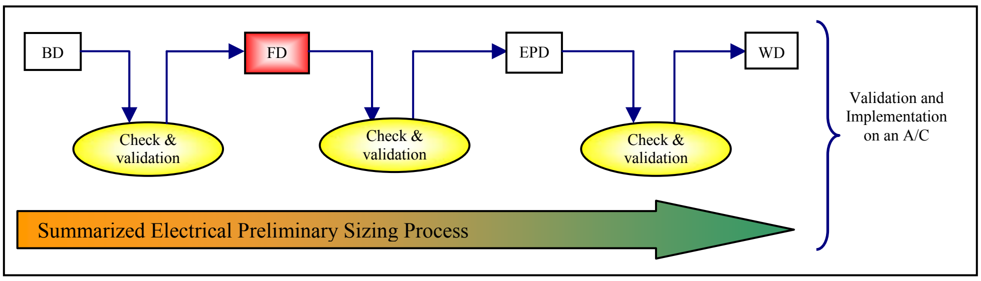
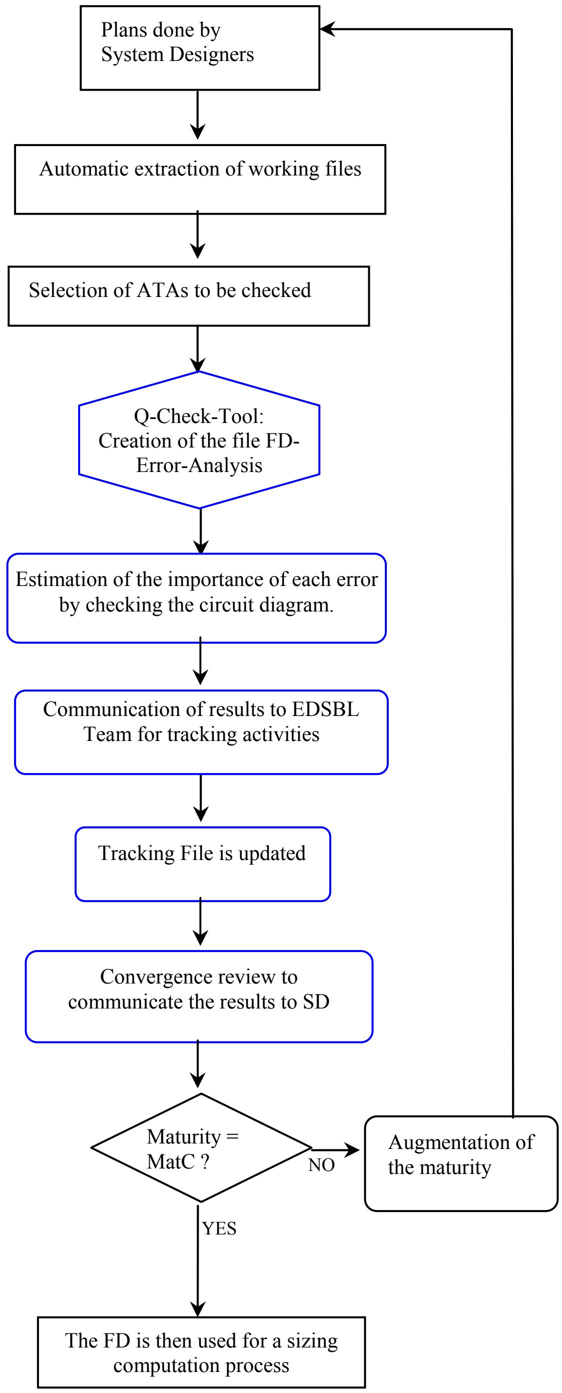


Figure 8: Sizing process

At each step of the life of a diagram, the diagram must fulfill requirements more and more difficult regarding electric installation rules. The BD represents only logical connection without any details regarding wires, whereas the WR is very detailed, with the gauge, the color … of each wire for example. More details about FD, BD, EPD and WR can be seen in APPENDIX 2

4 THE FD QUALITY CHECK ACTIVITY

The pre-sizing team is responsible for the check of Functional Diagrams (FD). Its mission is to report to system designers all the mistakes found in diagrams, to do the necessary manual corrections, and insure the quality of electric diagrams. They can accept a diagram or reject it, and in this case, the system designer has to do a new issue of the diagram. The pre-sizing activities can be roughly summarized by Figure 9:



Four files are extracted, for each drawing reference, with different extensions: .csv (Excel); .tif (Picture); .ssz and .xml

EDSBL Team weekly selects the ATA and the Sub-ATA to be checked according to the advancement of the diagrams

This software checks the consistency between plans (csv files) and databases (APEDD, SSL, FSI List …)
The file created is a list (Excel file) with all the errors found on the FD (e.g. inconsistence between type and gauge for a cable).

The consequences of an error can be more or less severe, that must be checked in accordance with the circuit diagram. Comments/details about each error are also given to the SD to correct them

Due to subcontracting activities, regular tracking is necessary.

Electrical Schematic Diagrams Common Repository (ESDCR) is a tracking file, and has to be updated according to the status of the plan.

A review is organized by the SD to collect all the errors found by the different departments (customers) working on his plans.

If a circuit has been validated, its maturity is incremented.

The Sizing team will use this configuration of the circuit as input data to compute the quantity of wires (e.g. length, weight etc.).

Figure 9: Flowchart of the FD Check Activity.

In the diagram above, the steps drawn in blue are the specific actions done in this master thesis, for these subcontracting activities
The system designers define diagrams, and then extract files from it. Especially two of them are interesting for pre-sizing team. One is the “CSV” (named like that due to the extension of the file xxxx.csv), which lists all the links existing in the diagram; the other file is the “TIF” (also named according to its extension), which is a picture of the diagram.

4.1 EXAMPLE OF A FUNCTIONAL DIAGRAM

Figure 10 is a functional diagram and its reference is HQV21296804001C

21 →ATA 21 = Air Conditioning
9 → NatCo code = in this case it is a German diagram
26 → Sub ATA 26 = Avionics Equipment Ventilation
804 → Plan 804 = number of this FD in this Sub-ATA
001C → Version = Version 1 issue C.

The CSV associated to this file is in APPENDIX 3

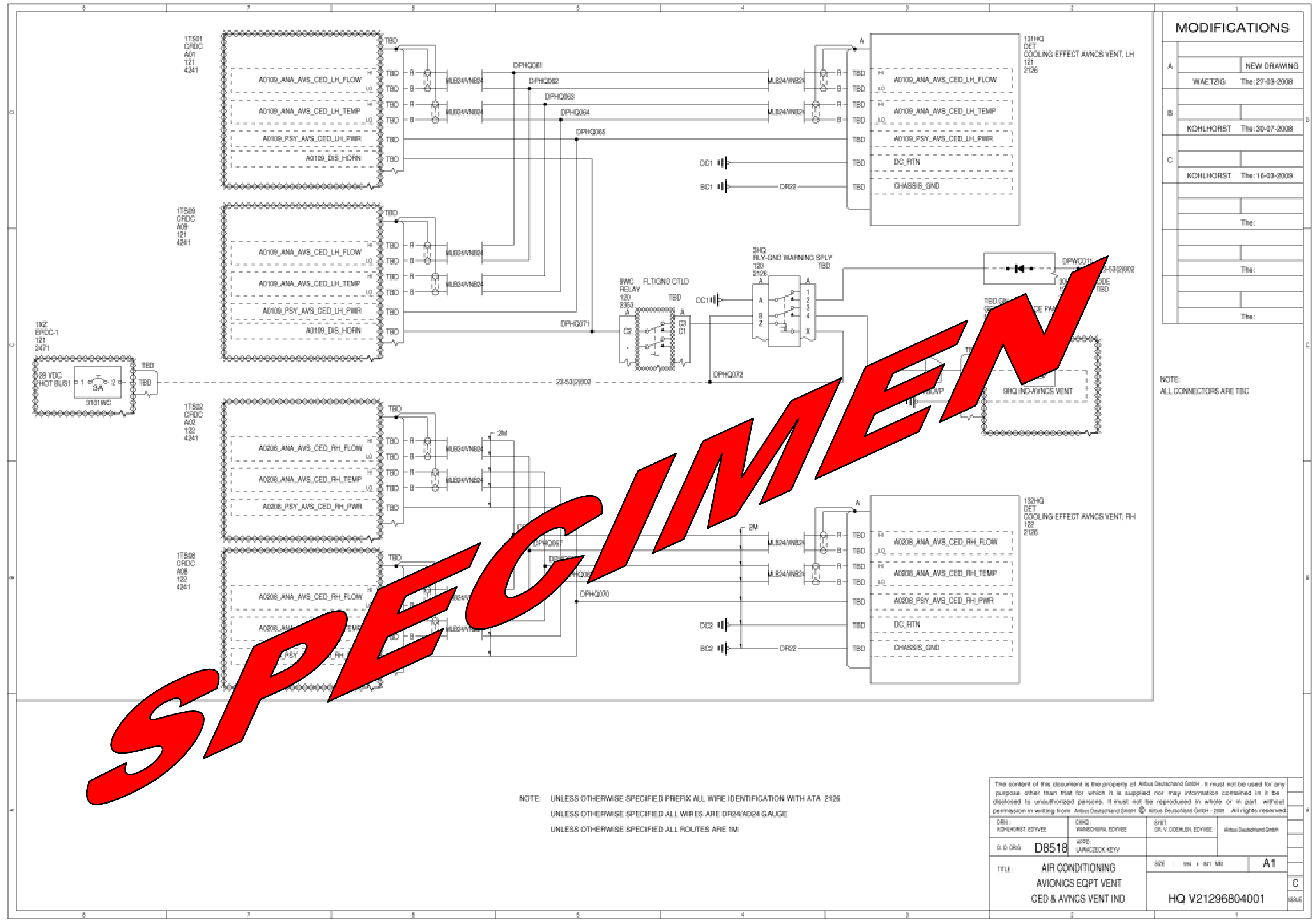


Figure 10: FD HQV21296804001C

The tool that was used to check the FDs is a software that was developed by AIRBUS: FD-Quality-Check tool. This software checks the consistency between diagrams (CSV) and databases: APEDD, SSL, FSI list, TDD etc. All the mistakes found are listed in a file (excel file) divided by type or error e.g. error on routes, error on definition of equipments etc…

Obviously, the different mistakes have different impacts on an electric network; consequences of an error can be more or less severe. Thus, each mistake that was found has to be checked in accordance with the circuit diagram (TIF); and comments about the errors are given to the System Designer that will provide a good improvement of the FDs.

To communicate the results, meeting reviews are regularly organized by the System Designers. These reviews regroup all the "customers" of the FDs that are (according to the maturity of the diagrams): the bench test team, the aircraft-zero team (first plane only for text on ground, it will never fly), the electric bundle team, and at last but not least, the pre-sizing team.
Each customer has different requirements, so all the necessary information are checked at least once (some information being necessary for several customers, they can be checked twice or even more).
When the FD is accepted, its maturity is updated, until it reaches the requirements of all the customers, then, it can be updated as an EPD, and be the final version of a diagram.

4.2 THE VERIFICATION TOOL

As it has summarily explained before, the tool developed by AIRBUS checks the coherence between the files and the databases. It has been developed using ACCESS application. Figure 11 presents the Human Machine Interface

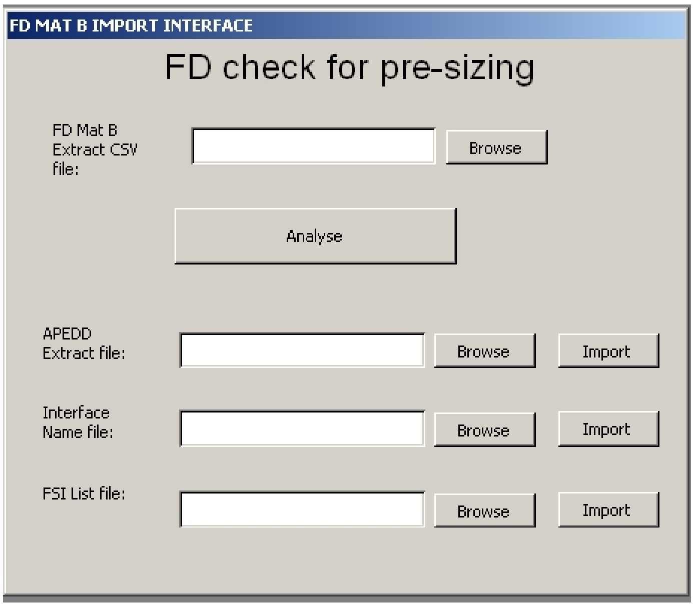


Figure 11: HMI of the FD-Q-Check tool

Different files have to be uploaded using it:

- The CSV file
- The APEDD: Aircraft Preliminary Equipment Definition Database
- The interface Name database: it is a database listing all the line names that a system designer can use.
- FSI list: Functional Standard Item: equipments that a system designer doesn't have to describe (relay, contactors, etc…)

- TDD: Technical Design Directives lists all the routes that can be used on a aircraft
- SSL: Standard Selection List lists all the cable, and their gauge that can be used on an aircraft.

Then, according to the errors found a report is generated. This report has to be checked using the TIF and comments from the system designers.

4.3 ANALYZE OF ERRORS

The table below represents a part of one report with errors and comments that can be found in a CSV file

Table 1: List of Type Gauge Errors

CIRCUIT	DRAWING_REF	TYPE_GAUGE_STATUS	CABLE	GAUGE	COMMENTS
2751	CVV27591805-01C	First Type/Gauge not valid for A350	MMG	24	KO- Not defined in the SSL
2751	CVV27591806-01C	First Type/Gauge not valid for A350	MMG	24	KO- Not defined in the SSL

In this figure, the information about the errors are given

- Circuit: that row refers to the ATA of the diagram (in this case: ATA 27; Sub-ATA 51)
- Drawing reference: is the name of the diagram
- Type_Gauge_Status: is the type of error found (in this case, the type of gauge used is not allowed for the A350 aircraft)
- Cable / gauge: references used by the system designer for this cable in fault
- Comments: that is added by the pre-sizing team in order to detail which is the level of severity for this error (in this case the status is KO, the diagram is not accepted by the pre-sizing team)

This information, with comments, will be communicated to the system designer during the meeting review (or, of course, by email if the modifications to do are simple and not many).

APPENDIX 4 gives a non-exhaustive list of error highlighted by the pre-sizing team

The main action of the pre-sizing team is to return efficient comments to the system designers. The more detailed and the more accurate the comments are, the easiest it is for the system designer to correct its diagrams.

This team also has to recommend to the software developer some new checks/verifications. Actually, there are always some updates to do in order to improve the tool. If the tool could check more details, the quality of diagrams will be better and the input data for the sizing team will be improved. To do that, suggestions are done, in order to do some comparisons between the requirements of the sizing team and the constraints that have to respect the system designer.

4.4 IMPROVEMENT SUGGESTED BY THIS MASTER THESIS

4.4.1 Zoning Consistency Check (ZCC)

The first improvement concerns the localization of equipments in order to reduce the length of cable and then the weight of these cables. The change is a new verification of the localization of certain equipments, according to their zone in the aircraft.

Description of the method

With the help of the informatic engineer responsible for the FD-Q-Check tool modifications, a new method to check the pertinence of the utilization of an equipment according to its localization (zone) was developed in this work. Actually, an aircraft is divided in zones and each equipment has then its particular zone. Figure 12 shows the division in zones of an A350

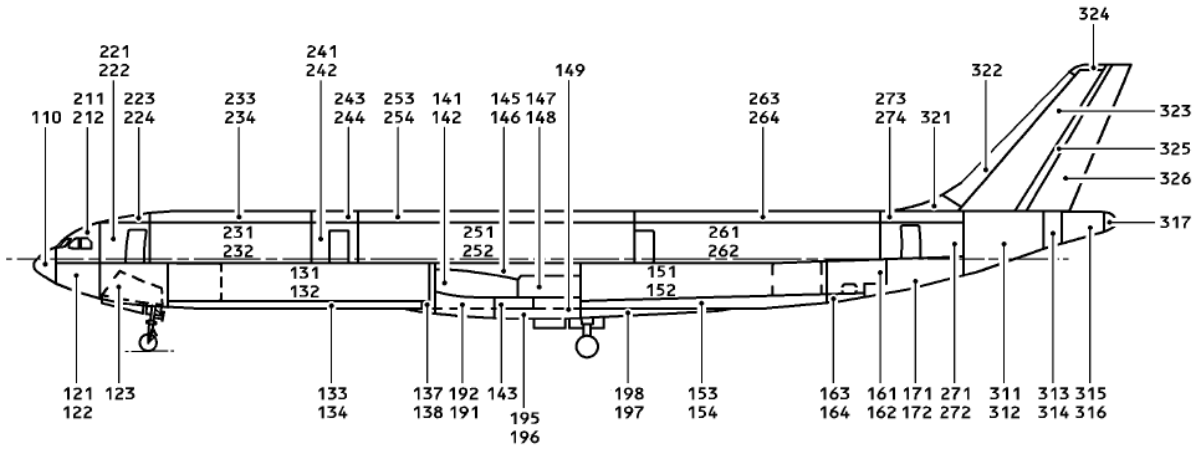


Figure 12: cutting of an A/C

In one zone there are obviously several equipments; these equipments are connected together or with other items as electric supply, circuit breaker module etc. The power electric installation in an aircraft goes through the different zones of the aircraft. The two sources of energy (engines) are then distributed all along the aircraft, as it is summarized in Figure 13

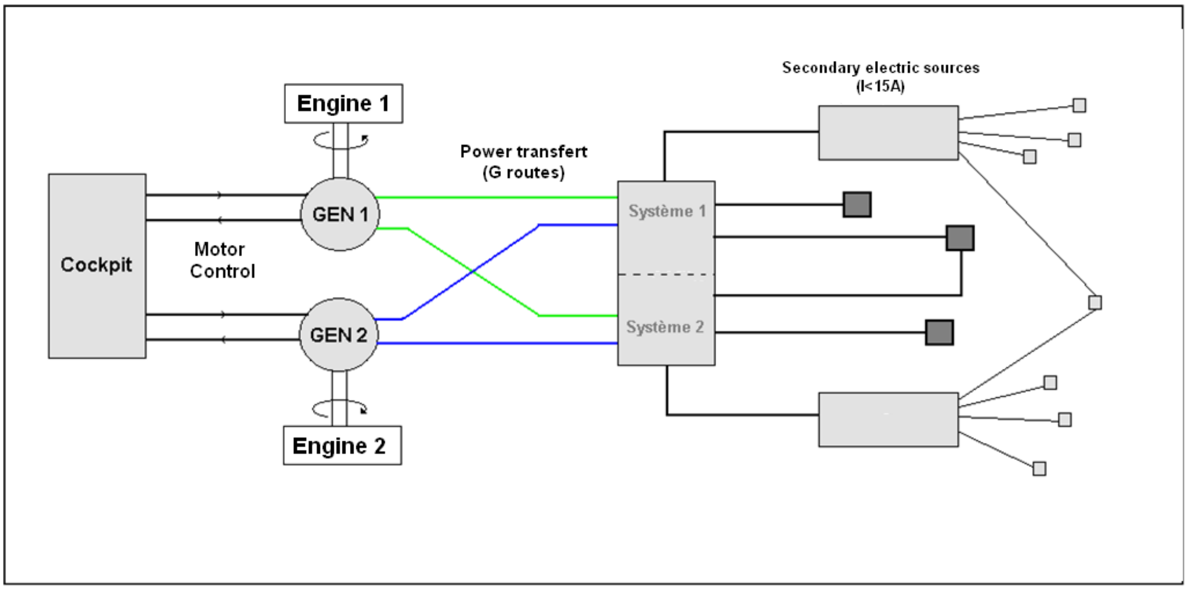


Figure 13: schema of power electric distribution

If an equipment needs to be directly supplied by an electric source, it seems logic to use the closest one. These sources are mainly localized all along the middle line of the fuselage, to allow an easy connection with the systems. The localization of theses electric sources is represented in Figure 14.

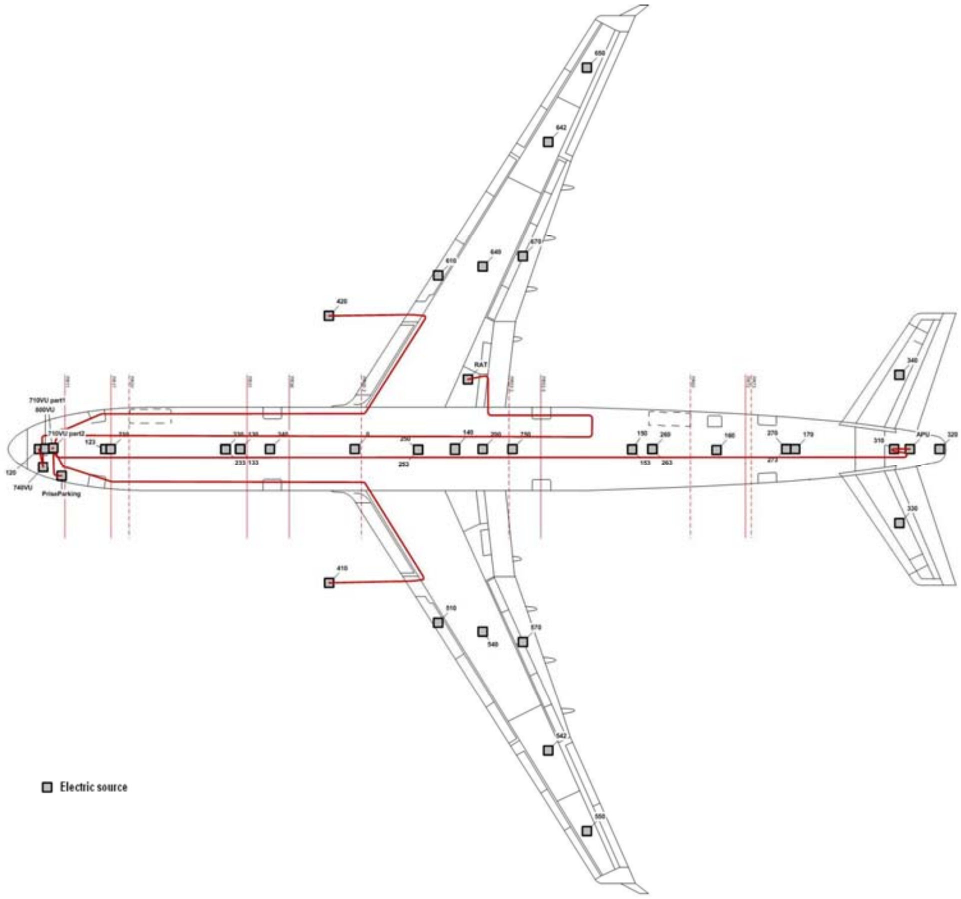


Figure 14: Localization of electric sources in an A/C

There are different types of electric sources (12 VDC, 28 VDC, 115 VAC …) for obvious reasons of confidentiality, there are not differentiated in Figure 14.

The system designers have to connect there systems to the closest source of energy, but it happens that a system is not connected to a source further away that the closest one. In this case cable could be shorter, so some weight can be saved.

The tool now checks the distance between the source used and the equipments. One can see, whether this distance seems too long, if there would be another source closer to plug the equipment on.
The advantage is obviously to reduce the length of cable used and so the weight of wires in the aircraft. Figure 15 explains the main idea of this new process:

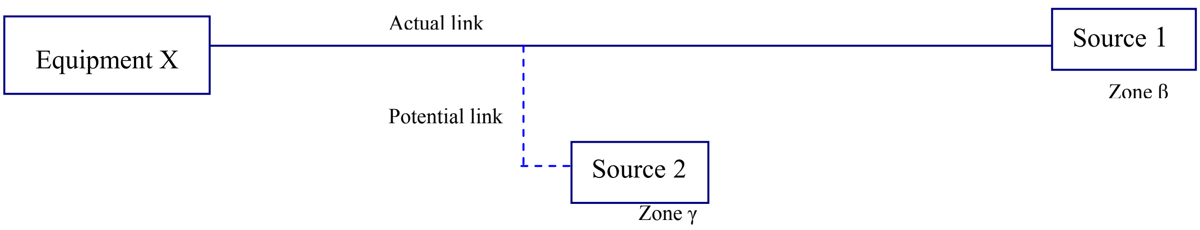


Figure 15: Example of implementation for 2 sources for a single equipment

The tool now checks the length between the zone α and the zone β. If this zone is bigger than 10 meters (arbitrary value choose in accordance with AIRBUS) then an error is signalized. In this case, I check using the TIF of the FD, and the Item_Localization_Table_V1.8 (last version I used) if I can find a closer source. The table below represents the Item_Localization_Table

Table 2: Item_Localisation_Table

	Source 1	Source 2	Source 3	...	Source n
Zone	131	121	172	...	152
localization X (m)	8,37	12,86	47,12	...	21,45

X is the horizontal position of the source in the aircraft in meter.

Observe that the name and the localization of the electric sources in this example are fictitious for illustration purposes

Of course, this method is true for energy supply, but it can also be applied to other systems and that is one of the good advantages of this method, even if it cannot be applied to all items.

Implementation of this improvement

In a first time, one assumed that this new verification could have been implemented for the verification of the localization of all equipments. But it quickly appears that this check was too ambitious. Actually, the check was too long due to the number of equipments but also due to the number of cross-references between FDs. One FD is often linked to others FDs using cross references, the link can be easily follow for some equipments, but it is too much work to do it for all of them. Our pretensions had unfortunately to be revisited.

So in accordance with AIRBUS, the decision was taken to analyze only certain equipments. The test was then limited by two parameters: the distances of equipments between two different zones are tested, and only a list of predefined equipments is tested

If two equipments are in the same zone, the distance between them is not tested. The system designers have to be trust for the implementation of equipments in a given zone. That is why this test has been implemented only for some equipments. The list contains the equipments that are often used and are impacted by this new verification.

The list contains the localization of , CRDC (Common Remote Data Concentrator), RCCBM (Remote Control Circuit Breaker Module) and EPDC (Electrical Power Distribution Center)

Results of the ZCC

The table below represents a comparative study that has been made before validating the new tool. The check has been done for more than 500 FDs.

Table 3: Results of Zoning Check Consistency

ATA	Length of cables wthout the ZCC	Weight of cables without the ZCC	Length of cables with the ZCC	Weight of cables with the ZCC
2123	87,00	33,60	81,00	41,03
2172	131,64	39,29	131,64	30,70
2277	64,41	43,08	38,54	19,57
2351	121,03	37,90	112,98	68,02
2431	214,68	71,35	175,78	78,83
2467	19,49	7,26	19,49	8,99
2518	126,69	86,89	108,13	74,02
3141	105,49	56,50	105,49	61,28
3231	320,59	214,19	320,59	230,40
3513	20,35	5,83	20,35	12,56
3521	123,19	82,08	65,32	21,67
3612	106,04	6,03	87,38	24,00
Toal:	1440,59	684,01	1266,69	671,06
		saved:	173,90	12,95

It should be mentioned that the values in the table above are just example.

The lengths in the table above are given in meters and the weights are in kilograms. The weight has been calculated using the length of the cable and a table giving the mass per meter according to the gauge of the cable. The computations assume that no cable were protected (over-braiding, over-shielding etc.)

The results obtained are not that impressing, the weight saved in only around 9 kg. However, it has been used for two applications:

- It has been used, in some cases, to highlight the presence of mistakes in the use of EPDC, RCCBM and CRDC to the system Designers

- The weight saved is not so negligible. The weight in a plane is a very important data, so that regarding AIRBUS requirements, the weight saved is important.

Due to these two advantages, this new check, the Zoning Consistency Check has been implemented to the FD-Q-Check tool. The verifications are done for all the FDs, and the results are reported to the System Designer in order for them to improve the quality and the reliability of the electric diagrams.

4.4.2 Grounding Data Base

For previous programs, before the A380 family, the grounding management was most of the time made using the same material, the same dimensions for the cables between the equipment and the ground (structure). Some exceptions were done for some items needing high current intensity. For these special equipments, bigger links, bigger grounding cables were used. In these cases, the decision to change the size of the grounding cable to protect an equipment was under the responsibility of the System Designers.

Then, the Electric Installation Department, particularly the Electric Bundle Department, created a list of different cables that should be used for return current networks, according to the properties of the signal carried. This list defines according to the intensity of the current which is supposed to go through the grounding cable, a minimum and maximum length, a gauge, and some precautions for their implementation on the structure of the aircraft. The most critical risk is of course the utilization of a too thin cable, but a too thick cable is not suitable either.
Each type of protection gets a specific reference, and this reference is used in all the circuit diagrams (FD, EPD, WD, etc.) The list thereby created has been added to a famous aeronautic standard for electric installation: the TDD92 (Technical Design Directive) and the TDD20.

The TDD 92:
This document describes the mandatory rules to be followed regarding electrical and optical installation in an aircraft.The official description of this Technical Design Directive is: “the aim of this document is to define requirements that take an active part in system operation, performance and safety analysis for a specific program” This document has to be respected when talking about Wiring Segregation Rules, Electrical and Optical Harnesses Installation, Harness Constitution and Handling, Standard Electrical Components Installation, etc. and at last but not least, regarding Grounding and Bonding Points - Lightning Protection.

For example, one of the recommendations of the TDD 92 regarding grounding cables is: “The thickness of the sheets to which grounding points are attached shall be consistent with the current carried (see table 4).

Table 4: Minimum thickness of structure (in mm) for grounding points

UP TO I (A)	THE LIGHT ALLOY STRUCTURE SHALL HAVE A MINIMUM THICKNESS OF E (MM) RESISTIVITY ≈ 2.8 μΩ/CM
20	0.6
50	0.8
100	1.2
150	2
200	2.6

Note: These dimensions are minimum requirement for electrical installation only. These values can be increased for mechanical reasons.

The TDD 92 also provides design requirements and explanations about grounding and bounding connections as it is shown in Figure 17

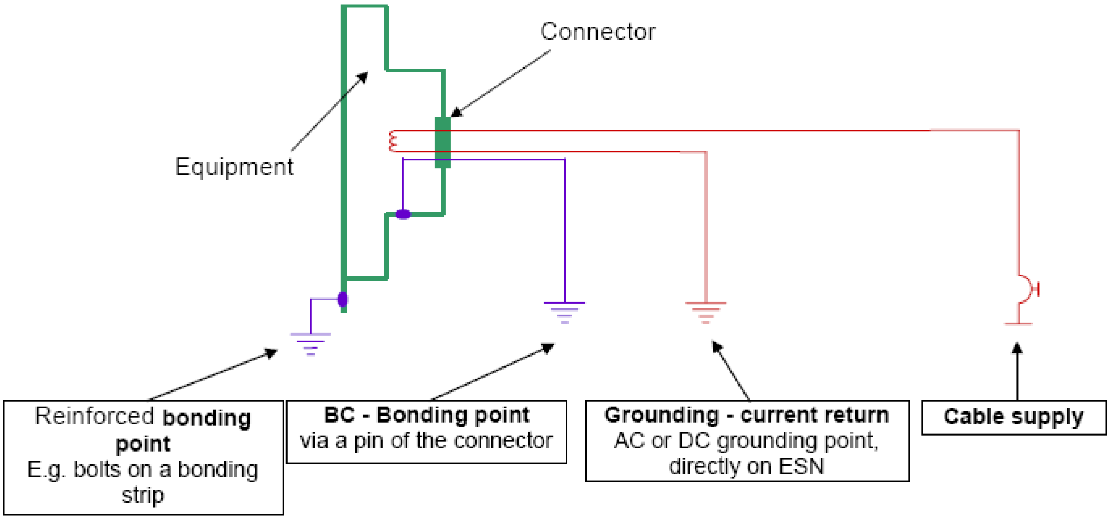


Figure 16: Bonding and grounding design requirement

<u>The TDD20</u>:
This document describes the Electromagnetic Hazards and Cosmic Radiation Protection and also Electrical Bonding Practices that have to be respected in an aircraft. The official description of this Technical Design Directive is: "The aim of this TDD is to define the EMH requirements, the design solution for the lightning protection of aircraft systems that affects system operation, performance and safety analysis for a specific program and the associated system installation requirements."
This document gives the following documentations:

- Electrical grounding refers to the establishment of a current path to the point of voltage reference. The electrical grounding is realized by either dedicated wires or Electrical Structure Network or a combination of both.
- Electrical bonding refers to the establishment of a current path between electrically conductive parts in order to assure electrical continuity. This path may be between two structural parts as well as between two points on a system ground plane or between ground reference and a part, circuit or structure element.
- Electrical current return refers to the establishment of a low impedance current path between the power supply reference (0 V DC, 0 V AC or AC Neutral) of an electrical component and the aircraft point of voltage reference.

So all the necessary information concerning electric and optical installations and protection, for equipments, power supplies… are defined and referenced in the TDD92 and TDD20

For an aircraft under development (e.g. A350XWB, A400M) System Designers use the TDD92, but mistakes are unavoidable. The innovation implemented by this master thesis consists in a check of the size of the grounding cable used in FDs. The aim proposed was to check whether the grounding cable is well adapted or if an improvement can be done.

The principle of the new verification

In almost all the electric diagrams, there are some grounding cables so for rapidity reasons, it has been defined, in accordance with Electric Installation Team AIRBUS, to check only utilization of the thickest grounding cables. The tool does not check all the grounding cables, it only highlights the utilization of the biggest ones. In this case, we make a feedback to the system designer and ask if the type of cable used is necessary and justified.

Basically, the process of this new verification is explained by Figure 18

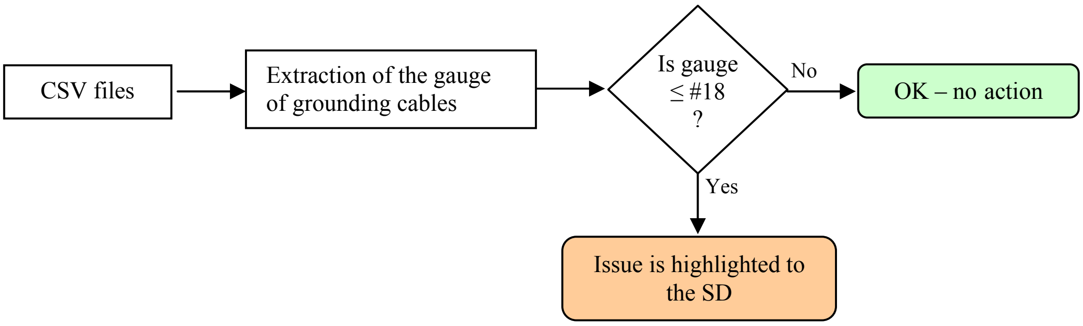


Figure 17: Basic process of the grounding cable verification

N.B: A small gauge designates a thick cable

But whatever the results are, the System Designer has a complete authority for this parameter, the Electric Reference Team has only an informative role. That means that we can only tell him that the diameter of a cable seems too big, if the System Designer do not want to change it, he is not forced by anything to change it.

Results

The result, except longer discussions with System Designers, has not been measured. The gain was obviously a gain in weight of cables, but due to the limited decisional power we have regarding grounding cables management, no numeric results can be given. The results are only qualitative no quantitative. However, a statistical could be performed in a later time, but it has not been done so far.

4.5 CONCLUSION OF THE FD-Q-CHECK ACTIVITY

The aim of this master thesis was to understand, check, and validate electric diagrams related to aeronautic requirements. The challenge faced was to fulfill the requirements of the industrial activities, in a quiet short time, and to suggest solutions to improve the quality of the diagrams that are the inputs data for the sizing team.

Interesting improvements have then been suggested by this master thesis since almost 13 kilograms of wires have been saved for the A350 aircraft. This weight saving in not minor, indeed, weight saving is one of the most important goal of AIRBUS, because it lead to a lower fuel consumption, and a lower environmental impact.

Other improvements cannot unfortunately be quantified, but proposed new way of working, and new verifications for this activity. They undeniably had a positive impact regarding quality of electric diagram for system designers.

5 A30X ASSEMBLY ACTIVITY

The A30X program aims at replacing the current A320 family, which is the AIRBUS most mature, stabilized and performing one. This plane is a medium size in the AIRBUS' range of products. The major improvement of this plane is it structure. Indeed, it will be made in Carbon Fiber Reinforced Plastic (CRFP), this material is supposed to lead to a minimized environmental impact. So far, this program is under development; actually the first flight of the A30X is planned 2017 in the best case.

5.1 NECESSITY OF A NEW PROCESS OF ASSEMBLY

But if the A30X should be the dignified substitute of the A320 and represent a real technological innovation, the consequences from the manufacturing point of view, for the A30X is to follow the challenging program targets:

- Rate: 40 A/C per month (above the 200th A/C).
- FAL working days: 10 days (above the 200th A/C).
- Consequent reduction of the number of electric components

The rate has to increase in order to reach the impressive number of 40 aircrafts per month - for comparison, the actual rate for the A320 is 35 aircrafts per month. In order to reach this rate, the Final Assembly Line (FAL) lead-time has to be reduced to 10 days. To achieve that, a new configuration - structural assembly – is to be considered. And at last but not least, the reduction of electric components is also a major goal.

These goals are particularly challenging with respect to the current manufacturing practices. They impose in particular a complete reorganization of the systems and structure assembly to reduce the FAL lead-time. New concepts have therefore to be investigated, with a specific focus on approaches allowing a fast production rate and an integrated design of the electric installation. This master thesis focuses only on electric installation (nor on handling, transportation neither structural issues). The reduction of the FAL lead-time could not be considered in this analyze, others investigation are planned for a later time, to solve this problematic.

5.2 PREVIOUS SCENARIO: THE "SAUCISSON"

During the master thesis, I had the opportunity to study the concept of the new scenario: the "French Baguette" or "Long Panel" that could be applied to the A30X. I also get a chance, to compare it to the actual scenario: the "Saucisson" or "Full Barrel" which is the standard scenario applied to the A320. Saucisson is a kind of Salami, and it is the way to cut it – vertical slices - which gave its name to this method.

The main difficulty with the "French baguette" scenario is that it is a complete unknown process, AIRBUS does not have any experience in the manufacturing / handling / assembly of long panels. But before a state of the art concerning the A320 is needed.

5.2.1 General configuration of the A320

First of all, this part gives a state of the art regarding A320 assembly technology and processes. This process is very well controlled by Airbus, the A320 Family Continues to be the Market Leader with Low-Cost Airlines, almost 4 000 A320 are currently in service. Figure 19 gives an exploded view of the mains pieces of an A320 with the engines under the wings.

Figure 18: A320 family industrial work sharing

But all the pieces of an aircraft cannot be assembled in the same time as in Figure 19. That would have too big logistic and storage issues. The assembly is in reality divided in several steps. These main steps of the assembly, before the delivery, can be seen in Figure 20.

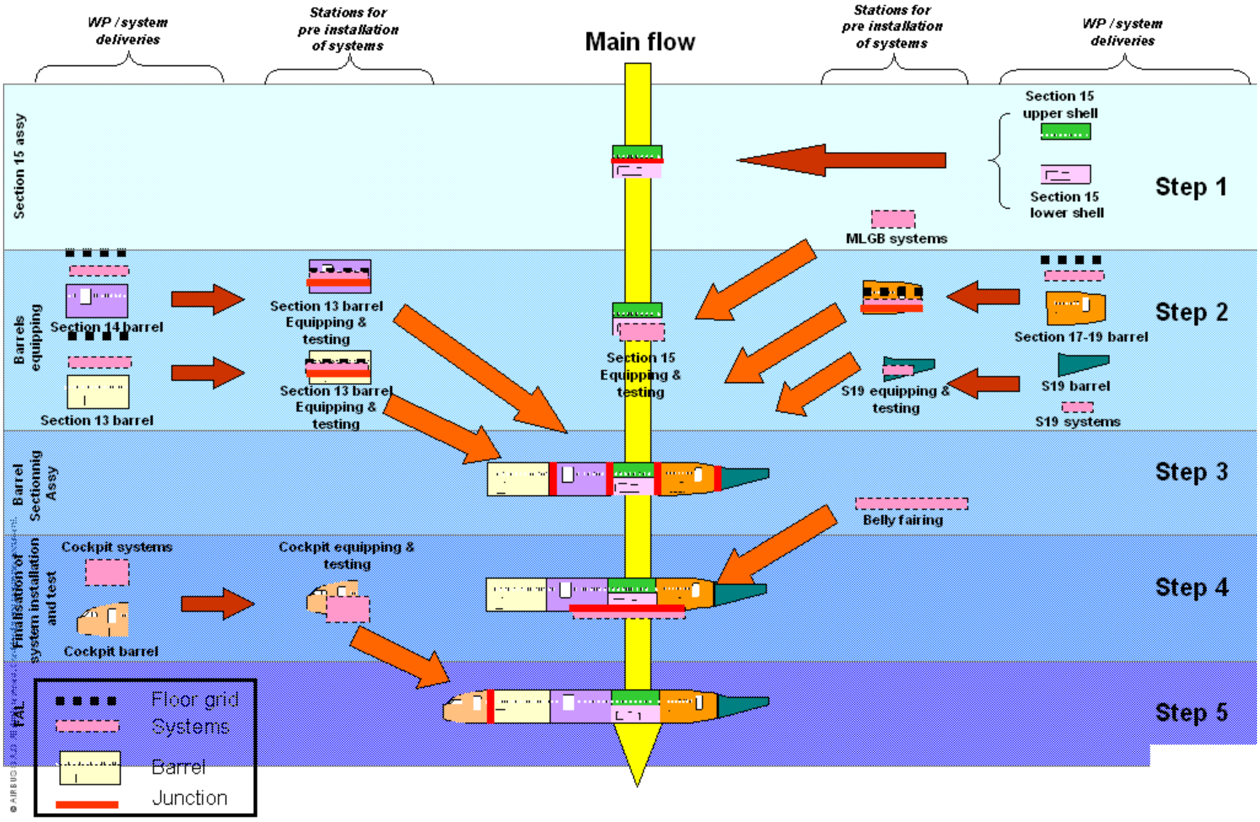


Figure 19: General current A/C manufacturing process

This scenario corresponds to the Saucisson one i.e. the aircraft is vertically "cut". This is a very well controlled process. The manufacturing process can be summarized in elementary steps: The parts and systems are designed and sub-assembled at the beginning of the manufacturing process. (That corresponds to the steps 1 and 2 in Figure 20), they are afterwards installed and assembled in Sections in various AIRBUS plants according to the A/C family (Steps 2, 3 and 4)., and finally, all the elements are transported to the FAL where the A/C is definitely manufactured, equipped and tested before being delivered to the customer (Step 5).

The A320 aircraft has been produced now for more than 20 years in Europe following this process (the manufacturing knowledge has even been sold to Chinese). Details about the junction of two barrels are given in appendix APPENDIX 5. So an evolution and the development of a more performing aircraft is indispensable.

The 20 years of experience showed that this scenario is a good solution from stress point of view and for system installation but the automation of installation is difficult in closed structure.

5.2.2 Electric connections

When one speaks about reduction of electric installation/components, one particularly speaks about length, weight of cables and also about the number of connectors. The weight of connectors is clearly not negligible; it can represent more than 250 kg on an aircraft. But one will later see that the new scenario envisaged will not lead to a reduction of the length or the weight of cables, only the number of connectors will be impacted

Concerning the electrical connections, the harnesses are most of the time manufactured with their plugs/sockets. Their length is fixed so that there is no cutting to perform during the installation process. They are plugged together via interface plates located a few frames apart from the connection (typically 3) as it is shown by Figure 21. This distance is necessary to facilitate the mechanical junction. Only for some particular cases (e.g. feeders), harnesses are made longer than necessary. They are then cut and the connecting devices are installed at the FAL level.

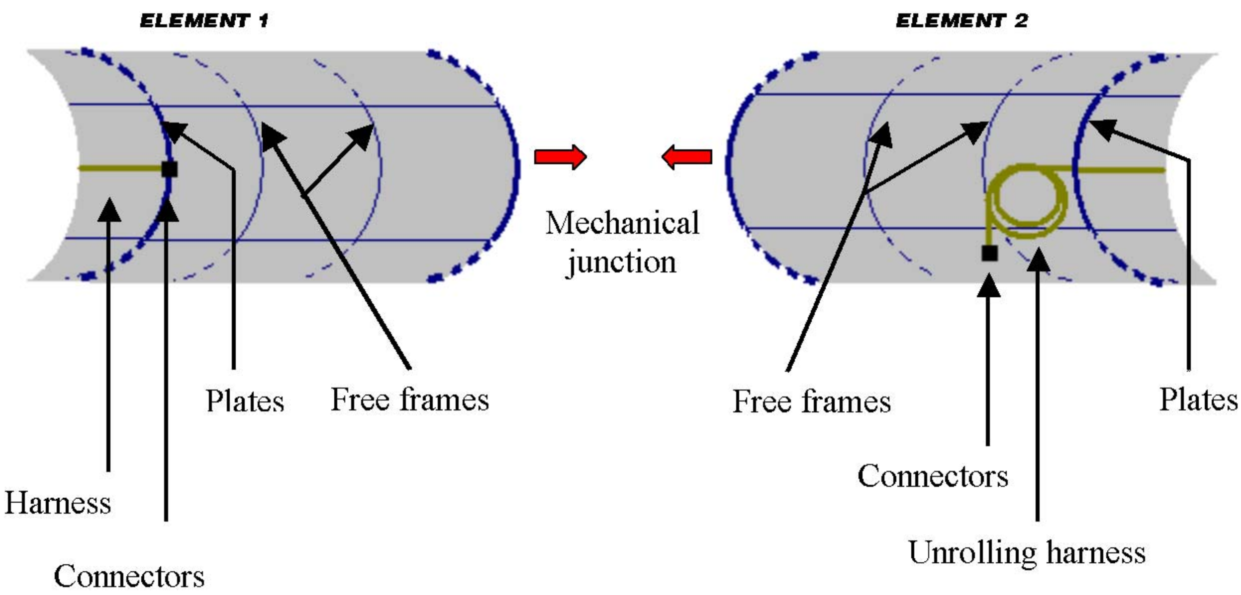


Figure 20: Electrical connection between two elements

Advantages and drawbacks about unrolling harnesses utilization are given in APPENDIX 6

According to the responsible of the manufacturing processes for A320 A/C, the number of connections is different for each junction, between 60 and 80 connections at the frame 35 (junction forward / central fuselage), 10 connections for the tail of the A/C (APU starter), 10 connections for the VTP, and around 15 for each engine.

To sum up this process, the major drawback is the serialization of the process. The mechanical and electrical assemblies are distinct, which increases the FAL lead-time. A process in which the different tasks are paralleled would be more efficient. From the electrical installation view, a gain in time would be to reduce the number of connectors to plug together i.e.: have a FAL assembly process different from the A320 one.

5.3 NEW SCENARIO: THE FRENCH BAGUETTE

These dimensions are almost the same than for A320, it is juts a bit bigger. The main difference concerns the material used for its fuselage. Actually the fuselage is a not in metal anymore, it will be, as said before, made in composite (CRFP) + Copper Foil (195 g/m²)

5.3.1 The Electric installation related to composite fuselage

The electrical installation baseline has been established on the basis of a “risk” scenario in which the Electric System Network (ESN) is described in Figure 22. Because the structure of the A30X is manly composed using non-conductive materials, some solutions have to be found, particularly regarding EMI and return current networks.

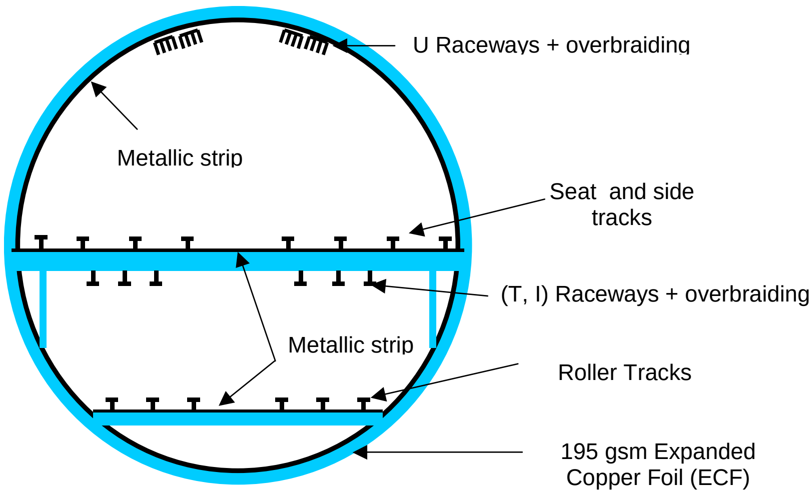


Figure 21: A30X electrical structure network

That represents the different possibilities that would be available for electric harness in the A30X. All these components are used in order to fix or protect the electric connections. The U raceways for example are a good protection against ElectroMagnetic Interferences; the seat tracks are also used, for return current network, due to their good conductivity. These equipments are already used for A380 and 350 programs, but will be developed for the A30X program. So many change will be implemented on this Aircraft family, regarding electricity installation, but maybe also regarding fuselage assembly.

5.3.2 The long panel assembly

This scenario is a « multi-panel » one in which the shell is cut in the longitudinal dimension, creating two shells of the A/C structure: the upper and lower shell as it is represented in Figure 23.

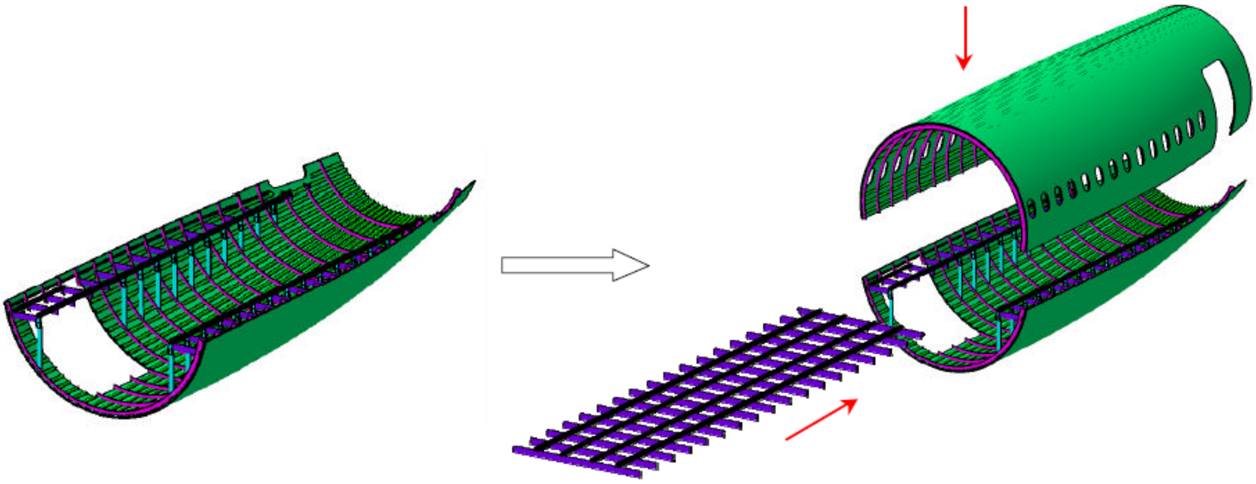


Figure 22: Long Panel scenario description

Many other configurations of assembly have been proposed, but this one seems for AIRBUS the most realistic and the one that corresponds to a real technologic improvement. The floor is then electrically pre-equipped and installed in the barrel before the upper part is assembled to the lower one. The seats, the luggage compartments and all others equipments, would be installed later.

Applied to the nose/centre/rear fuselage, the corresponding A/C division is represented by Figure 24

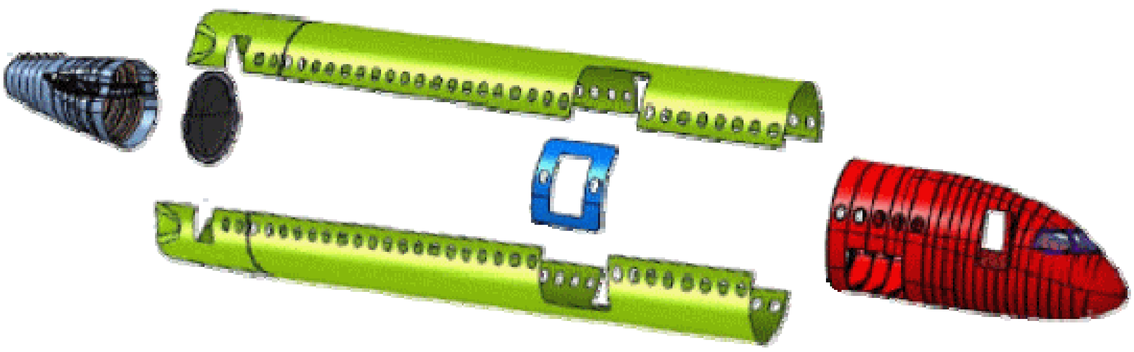


Figure 23: Decomposition of the A/C into elementary parts. Long Panel scenario

One can clearly see here the new A/C sectioning involved by this technique, concerning mainly the A/C central zone. The two extremities (front and back fuselage) are the same than for the previous configuration (full barrel), so regarding electric installation, modifications, and sizing activities, these two parts are not as “essential” that the central part.

The assembly process divided step by step for the A30X, or more generally for the French baguette scenario, is shown by Figure 25.

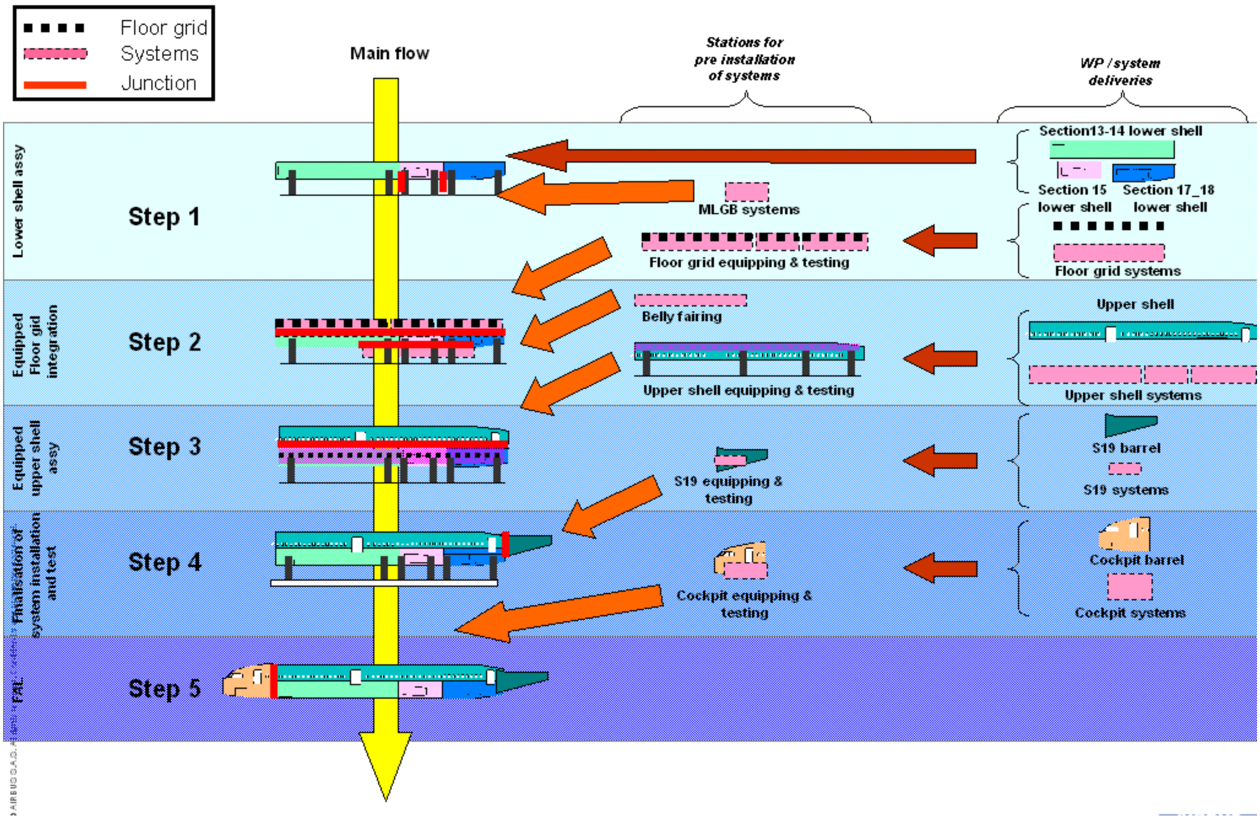


Figure 24: Long panel assembly sequence

The FAL stage correspond to the Step n°5 in this scenario during which the nose is assembled to the rest of the fuselage. As in the full barrel, all the different elements are equipped before being assembled.

The first investigations concerning this new assembly process gives mitigated results, it seems that AIRBUS does not have experience in very large manufacturing/transport/assembly of very large panels, it will also be very difficult to reach the rate of production (40 A/C per month), but the FAL lead-time will be shorter than for the A320 due to parallel work, and finally that would enhanced ergonomics due to flexible positioning of half-fuselages

Of course, deeper analyses are needed to confirm this first impression about the French baguette scenario. But the task of this master thesis was only about electric installation improvement. So only the evolution of the number of connectors has been investigated.

5.4 ELECTRIC ROUTING FOR BOTH SCENARIOS

The study of the number of connectors has been performed using a specific tool: IRIS (version 3.0.4.1). IRIS means Interactive Routing for Installation of System It is a software developed by CIMPA (Centre d'Intégration Multi métier de Productique Appliquée), which is a subsidiary company of AIRBUS specialized in computer-integrated manufacturing and in industrial data processing.
The aim was to modify the junctions of the mock-up of the A320 to implement on it the A30X junctions. Figure 26 shows a mock-up of an aircraft represented using IRIS

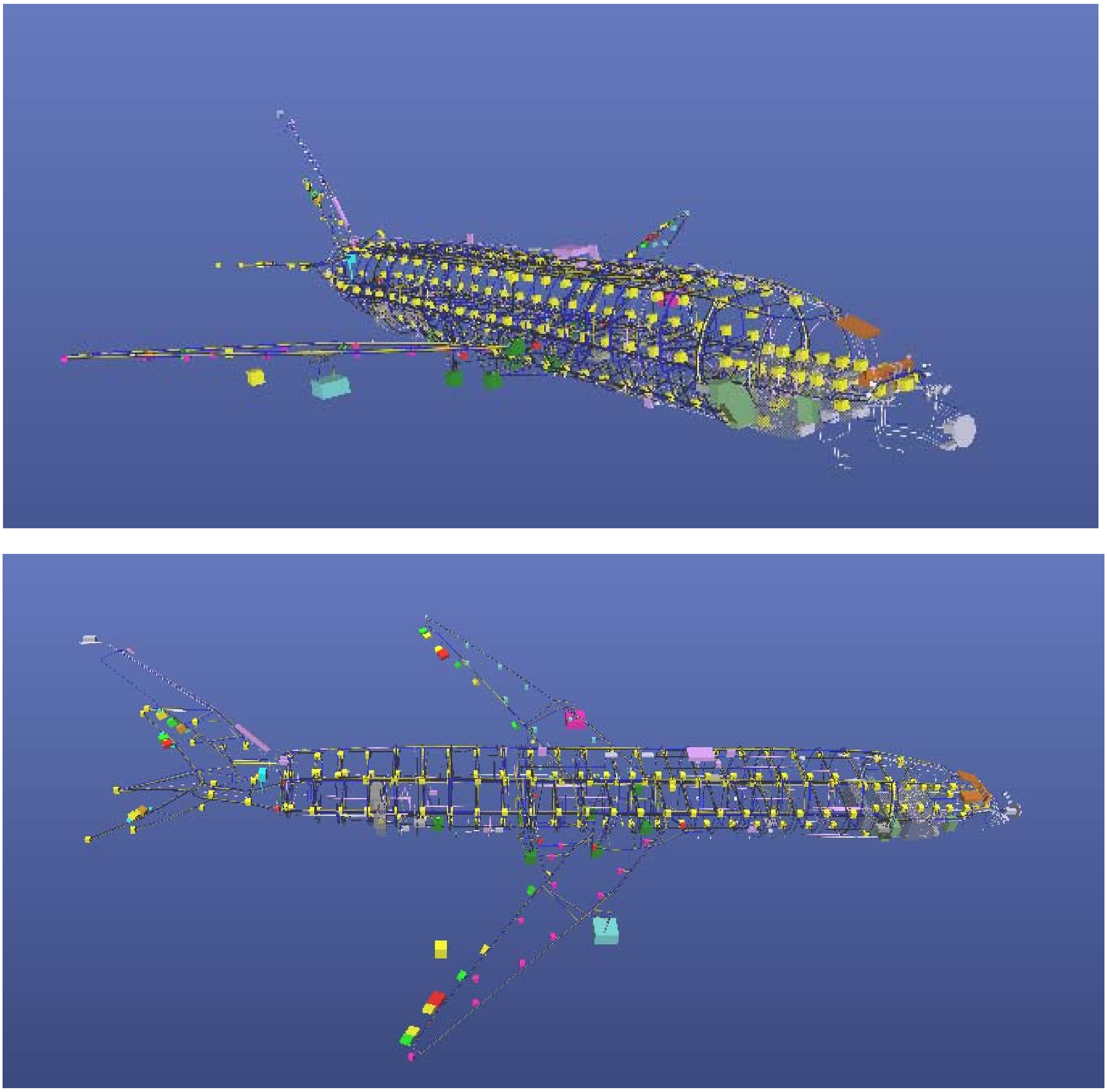


Figure 25: IRIS mock-up – General configuration.

Figure 26 is composed by two pictures of the general mock-up. One can see the pathways of the main roads, and the main electric components.

But as it has been previously explained, regarding electric installation, the modifications impact only the central fuselage. Figure 27 shows the pathways of the central fuselage.

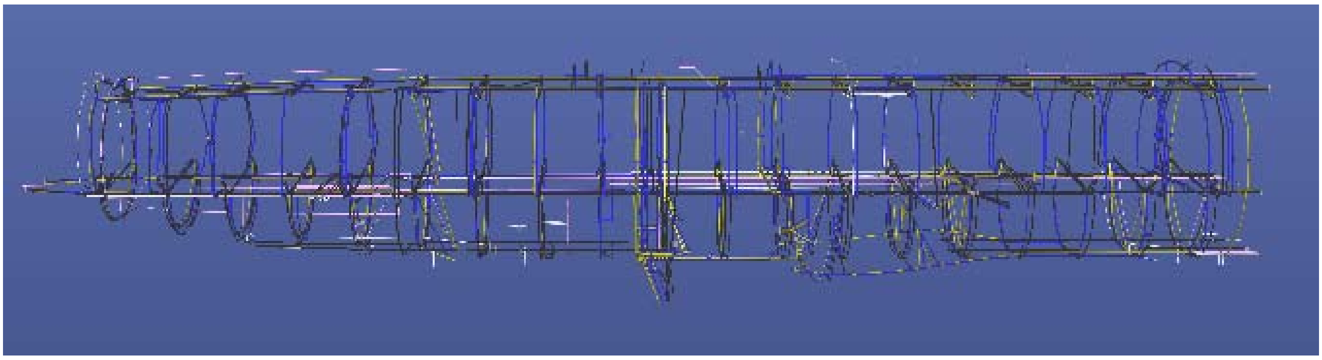


Figure 26: pathways of the central fuselage

The analyses are mainly done by modifications of the cutting. To see the difference implemented on the mock-up, Figure 28 and Figure 29 respectively show the different sections of the A320 and the A30X.

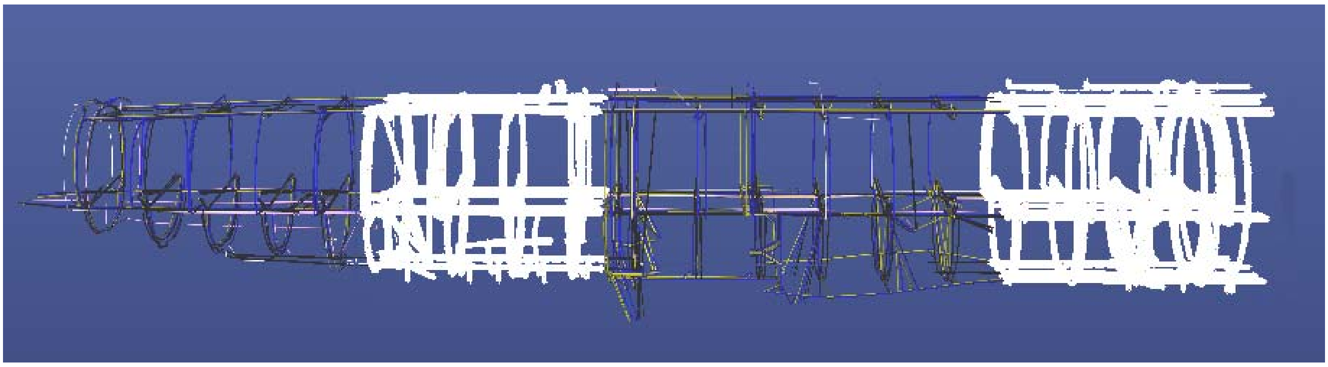


Figure 27: Saucisson scenario using IRIS

In this representation of the actual A320, the central fuselage has been divided in four barrels. Two of them have been selected on Figure 28 to highlight the vertical junctions

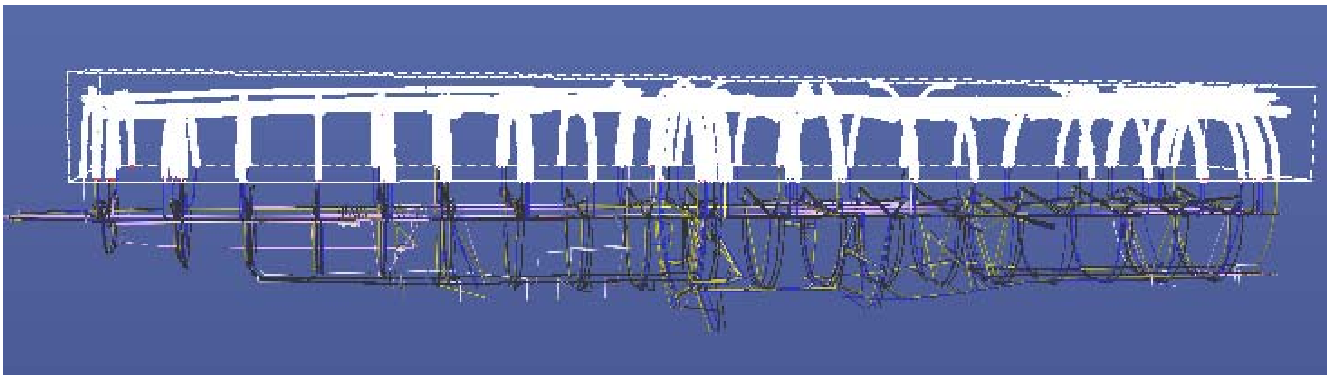


Figure 28: French baguette scenario using IRIS

On this mock-up, the upper part has been selected to highlight the horizontal junction. Between the two mock-ups, only the junctions are not localized at the same place, but the pathways are exactly the same. And using these figures, it is easy to see that regarding cables (weight, length, etc.) there is no difference between the two mock-ups, the difference is only regarding number of connectors.

5.4.1 Comparison and Results

A second version of the French baguette mock-up has been established to optimize the first one. In this optimized mock-up, the number of connectors between the bilge and the upper panel reduced to its maximum (it was not necessary to reduce the number of vertical links in the full barrel assembly)

The optimized mock-up has still the same amount of wires that are going from the bilge to the upper panel, but the wires are grouped together to limit the number of connectors. However, some inevitable rules had to be respected. First, the wires cannot be too much grouped together; the resulting diameter cannot be bigger than 5 centimeters (to be able to go thought predetermined raceways). Then some segregation rules have also to be respected. The requirements of this rules force to group wires of the same type. E.g. power lines have to be together, and cannot be group with a signal line. That has been established in order to limit interference risks, and other perturbations that could happen.

So the comparison of these tree mock-ups summarized regarding electric installation i.e. the number of connectors and their weight can be see in Table 4.

Table 5: Comparison of the assembly scenarios

	Saucisson	French baguette	optimised French baguette
Number of connectors	1261	915	863
Weight of connectors [kg]	231	158	153
Max diameter of harness [mm]	41	38	38
% of non-routed cables	< 5%	< 5%	~ 8%

One can see that the impact regarding electric installation is positive. The number of connectors needed for the French baguette scenario is lower than for the Saucisson scenario. So according to this study, this new scenario could save several dozens of kilograms. Regarding electric installation weight, this scenario is a good solution. But even if we focus on the electric installation, one cannot neglect others impacts. One can particularly think about mechanical issues.

It is easy to see that many issues have to be solved before that new process become feasible. Future studies will focus on these problems and try to find solution. But for this study, the result s positive, some weight can be saved, there are less connectors, so the Fine Assembly line lead-time would be reduced.

5.5 CONCLUSION OF THE A30X ASSEMBLY ACTIVITY

This study was a research work; actually this scenario is only a project work it has never been implemented on aircrafts by AIRBUS. When one speaks about research, one speaks of the necessity to centralize the information owned by various people, and try to make a pragmatic analyze, using that, we obtained coherent results. The results obtained confirmed the advantage of the new scenario, regarding electric installation, less connectors, less weight for the aircraft. But it was very difficult to focus only on electric installation impact, and not on the other constraints. Future research work will have to investigate these issues regarding mechanical impacts, transportation impact and so on. This research work is only one stone of a huge wall.

6 MASTER THESIS CONCLUSION

The first activity of this master thesis was to understand the difficulties and the responsibilities of a team work in an industrial context, and try to suggest solutions in order to produce better electric diagrams regarding quality, reliability, and weight impact. The improvements that have been suggested and implemented to the FD-Quality-Check activity lead to a weight saving near 13 kilograms, for an example made in this work. This weight is very important and shows that improvements have been useful. Aircraft manufacturers hunt down every single kilogram due to environmental and economic constraints (raw material price, and fuel price etc.). Other suggestions regarding electric diagrams verification has also been appreciated by the electric installation department members since the quality of electric diagrams have been increased.

The research activity has been performed to analyze and determine the potential of a change in the aircraft assembly process. It has shown the difficulties to realize a research work in an industrial field. Large companies such as AIRBUS have processes that have been used for a long time and thus very well controlled; and new processes are often not easy to implement. Particularly this kind of new scenarios for assembly, since the changes are huge, and many things are unknown. But even if it can be very surprising and potentially revolutionary, engineers of AIRBUS always consider new concepts, and try to improve their own way to do. Electric mock-ups have been done to compare the new scenario to the previous one. The optimized mock-up leads to a reduction of almost 400 connectors which represents more or less 80 kilograms. This is a very interesting conclusion regarding electric installation. However, future studies will have to focus on the resolving of others issues, as regarding mechanical issues, handling issues and so on.

7 GLOSSARY

EPDC	Electrical Power Distribution Center
APEDD	Aircraft Preliminary Equipment Definition Database
ATA	Air Transport Association
CRDC	Common Remote Data Concentrator
EPD	Extended Principle Diagram
EPDC	Electric Power Distribution Center
ESDCR	Electrical Schematic Diagram Common Repository
FD	Functional Diagram
FIN	Functional Item Number
FSI	Functional Standard Item
matA/B/C	Maturity A / B /C
RCCBM	Remote Control Circuit Breaker Module
SD	System Designer
SSL	Standard Selection List
SWRD	System Wiring Requirement Dossier
TDD	Technical Design Directive
VTP	Vertical Tail Plane
WD	Wiring Diagram
WIP	Work In Process

8 APPENDIXES

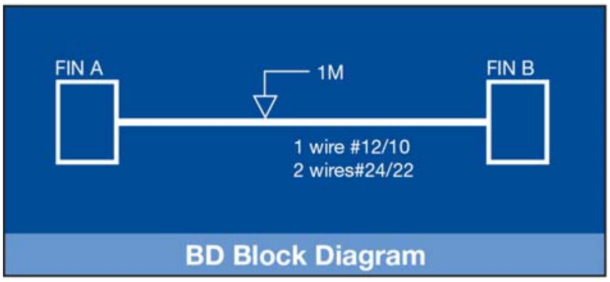
APPENDIX 1: List of main ATA

ATA	Description	ATA	Description
01	Certification Documents	44	Cabin Systems
02	Miscellaneous	45	Onboard Maintenance Systems
03	Miscellaneous (*General design)*	46	Information Systems
05	Time Limits – Maintenance	47	Inert Gas System
06	Dimensions and Areas	49	Airborne Auxiliary Power
07	Lifting and Shoring	50	Cargo and Accessory Compartments
08	Leveling and Weighing	51	Standard Practices and Structures
09	Towing and Taxiing	52	Doors
10	Parking, Storage and Return to Service	53	Fuselage
11	Placards and Markings	54	Nacelles/Pylons
12	Servicing	55	Stabilizers
20	Standard Practices – Airframe	56	Windows
21	Air Conditioning	57	Wings
22	Auto Flight	70	Standard Practices – Engine
23	Communications	71	Power Plant
24	Electrical Power	72	Engine
25	Equipment/Furnishings	73	Engine Fuel and Control
26	Fire Protection	74	Ignition
27	Flight Controls	75	Air
28	Fuel	76	Engine Controls
29	Hydraulic Power	77	Engine Indicating
30	Ice and Rain Protection	78	Exhaust
31	Indicating/Recording Systems	79	Oil
32	Landing Gear	80	Starting
33	Lights	85	Installation Drawings – Piping
34	Navigation	88	Structural Test
35	Oxygen	89	Flight Test Installation
36	Pneumatic	91	Main Wire Routing and Wiring List
38	Water/Waste	92	Electrical/Electronic Common
42	Integrated Modular Avionics	92	Installation Engine Data *(WDM*

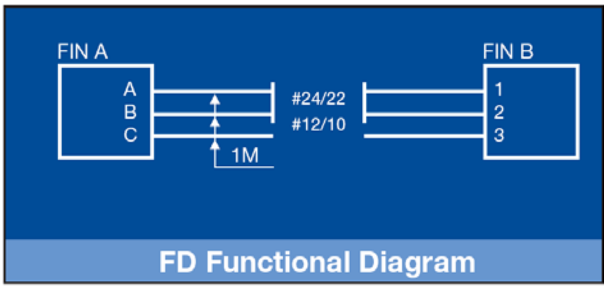
APPENDIX 2: The different diagrams

There are 4 different types of Electrical Schematic Diagrams existing for the A350XWB program. They can be briefly described as followed:

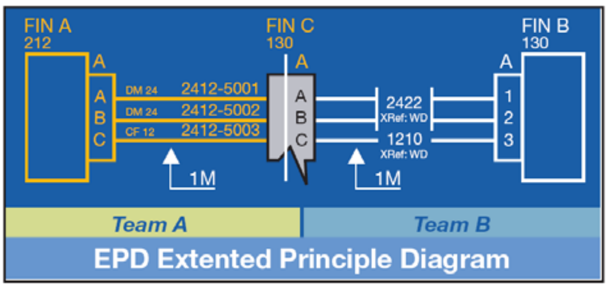
BD Block Diagram
The BD is a simplified description of system architecture. It is used for pre-sizing activities and route concept definition. It contains Connection Lines



FD Functional Diagram*
The FD specifies the functional electrical wiring of a system. It is used for System definition, pre-sizing activities, EPD design and test purpose. Two different maturity levels exist (MAT B & C).
It contains: Logical Wires



EPD Extended Principle Diagram
The EPD is illustrating the interconnections between items of a circuit while defining physical wiring for the responsible section (wire numbering, production breaks, interconnection modules, pin allocation…). It is used in order to understand and follow the circuit operation in sufficient detail and to define what will be installed on the responsible section. The EPD definition is used for manufacturing, testing and documentation. It contains: Physical & Logical Wires



APPENDIX 3: CSV extract of plan HQV21296804001C

II

ATA	Sub ATA	Functional designation	FIN	Virtual FIN	Zone	Panel	Channel	Interface name	I/O name	PIN name	Connector name	ATA	Sub ATA
42	41	CRDC-A01	1TS01 TBD		121	N/A		A0109 ANA AVS CED LH FLOW	HI	TBD	TBD	21	26
21	26		DPHQ061		121	N/A						21	26
42	41	CRDC-A09	1TS09 TBD		121	N/A		A0109_ANA_AVS_CED_LH_FLOW	HI	TBD	TBD	21	26
42	41	CRDC-A01	1TS01 TBD		121	N/A		A0109_ANA_AVS_CED_LH_FLOW	LO	TBD	TBD	21	26
21	26		DPHQ062		121	N/A						21	26
42	41	CRDC-A09	1TS09 TBD		121	N/A		A0109 ANA AVS CED LH FLOW	LO	TBD	TBD	21	26
42	41	CRDC-A01	1TS01 TBD		121	N/A		A0109_PSY_AVS_CED_LH_PWR		TBD	TBD	21	26
42	41	CRDC-A09	1TS09 TBD		121	N/A		A0109_PSY_AVS_CED_LH_PWR		TBD	TBD	21	26
21	26		DPHQ065		121	N/A						21	26
		DC1	GNDVN									21	26
42	41	CRDC-A08	1TS08 TBD		122	N/A		A0208 ANA AVS CED RH FLOW	LO	TBD	TBD	21	26
42	41	CRDC-A02	1TS02 TBD		122	N/A		A0208_ANA_AVS_CED_RH_FLOW	LO	TBD	TBD	21	26
21	26		DPHQ067		122	N/A						21	26
42	41	CRDC-A08	1TS08 TBD		122	N/A		A0208_ANA_AVS_CED_RH_FLOW	HI	TBD	TBD	21	26
42	41	CRDC-A02	1TS02 TBD		122	N/A		A0208 ANA AVS CED RH FLOW	HI	TBD	TBD	21	26
21	26		DPHQ066		122	N/A						21	26
42	41	CRDC-A02	1TS02 TBD		122	N/A		A0208_PSY_AVS_CED_RH_PWR		TBD	TBD	21	26
42	41	CRDC-A08	1TS08 TBD		122	N/A		A0208_PSY_AVS_CED_RH_PWR		TBD	TBD	21	26
21	26		DPHQ070		122	N/A						21	26
		DC2	GNDVN									21	26
42	41	CRDC-A01	1TS01 TBD		121	N/A		A0109_ANA_AVS_CED_LH_TEMP	LO	TBD	TBD	21	26
42	41	CRDC-A09	1TS09 TBD		121	N/A		A0109_ANA_AVS_CED_LH_TEMP	LO	TBD	TBD	21	26
21	26		DPHQ064		121	N/A						21	26
42	41	CRDC-A01	1TS01 TBD		121	N/A		A0109 ANA AVS CED LH TEMP	HI	TBD	TBD	21	26
42	41	CRDC-A09	1TS09 TBD		121	N/A		A0109 ANA AVS CED LH TEMP	HI	TBD	TBD	21	26
21	26		DPHQ063		121	N/A						21	26
42	41	CRDC-A08	1TS08 TBD		122	N/A		A0208_ANA_AVS_CED_RH_TEMP	HI	TBD	TBD	21	26
42	41	CRDC-A02	1TS02 TBD		122	N/A		A0208_ANA_AVS_CED_RH_TEMP	HI	TBD	TBD	21	26
21	26		DPHQ068		122	N/A						21	26
42	41	CRDC-A08	1TS08 TBD		122	N/A		A0208 ANA AVS CED RH TEMP	LO	TBD	TBD	21	26
42	41	CRDC-A02	1TS02 TBD		122	N/A		A0208_ANA_AVS_CED_RH_TEMP	LO	TBD	TBD	21	26
21	26		DPHQ069		122	N/A						21	26
		BC1	GNDVN									21	26
		BC2	GNDVN									21	26
21	26	RLY-GND WARNING SPLY	3HQ A		120	TBD				4		32	21
		DC1	GNDVN									32	21
		DC1	GNDVN									21	26
21	26	DIODE	30HQ		120	TBD						23	53
21	26	RLY-GND WARNING SPLY	3HQ A		120	TBD				2		21	26
21	26		DPHQ072		121	N/A						21	26
21	26		DPHQ072		121	N/A						21	26
23	53	FLT/GND CTLD-RELAY	9WC A		120	TBD				C3		21	26
42	41	CRDC-A01	1TS01 TBD		121	N/A		A0109_DG_HORN		TBD	TBD	21	26
21	26		DPHQ071		121	N/A						23	53

II

FIN	Virtual FIN	Zone	Panel	Channel	Interface name	I/O name	PIN name	Connector name	Route name	Cable Type	Gauge
DPHQ061		121	N/A						1M	MLB/VNB	24/24
131HQ	A	121	N/A		A0109_ANA_AVS_CED_LH_FLOW	HI	TBD	A	1M	MLB/VNB	24/24
DPHQ061		121	N/A						1M	MLB/VNB	24/24
DPHQ062		121	N/A						1M	MLB/VNB	24/24
131HQ	A	121	N/A		A0109_ANA_AVS_CED_LH_FLOW	LO	TBD	A	1M	MLB/VNB	24/24
DPHQ062		121	N/A						1M	MLB/VNB	24/24
DPHQ065		121	N/A						1M	DR/AD	24/24
DPHQ065		121	N/A						1M	DR/AD	24/24
131HQ	A	121	N/A		A0109_PSY_AVS_CED_LH_PWR		TBD	A	1M	DR/AD	24/24
131HQ	A	121	N/A		DC_RTN		TBD	A	1M	DR/AD	24/24
DPHQ067		122	N/A						2M	MLB/VNB	24/24
DPHQ067		122	N/A						2M	MLB/VNB	24/24
132HQ	A	122	N/A		A0208 ANA AVS CED RH FLOW	LO	TBD	A	2M	MLB/VNB	24/24
DPHQ066		122	N/A						2M	MLB/VNB	24/24
DPHQ066		122	N/A						2M	MLB/VNB	24/24
132HQ	A	122	N/A		A0208_ANA_AVS_CED_RH_FLOW	HI	TBD	A	2M	MLB/VNB	24/24
DPHQ070		122	N/A						2M	DR/AD	24/24
DPHQ070		122	N/A						2M	DR/AD	24/24
132HQ	A	122	N/A		A0208 PSY AVS CED RH PWR		TBD	A	2M	DR/AD	24/24
132HQ	A	122	N/A		DC RTN		TBD	A	2M	DR/AD	24/24
DPHQ064		121	N/A						1M	MLB/VNB	24/24
DPHQ064		121	N/A						1M	MLB/VNB	24/24
131HQ	A	121	N/A		A0109_ANA_AVS_CED_LH_TEMP	LO	TBD	A	1M	MLB/VNB	24/24
DPHQ063		121	N/A						1M	MLB/VNB	24/24
DPHQ063		121	N/A						1M	MLB/VNB	24/24
131HQ	A	121	N/A		A0109 ANA AVS CED LH TEMP	HI	TBD	A	1M	MLB/VNB	24/24
DPHQ068		122	N/A						2M	MLB/VNB	24/24
DPHQ068		122	N/A						2M	MLB/VNB	24/24
132HQ	A	122	N/A		A0208_ANA_AVS_CED_RH_TEMP	HI	TBD	A	2M	MLB/VNB	24/24
DPHQ069		122	N/A						2M	MLB/VNB	24/24
DPHQ069		122	N/A						2M	MLB/VNB	24/24
132HQ	A	122	N/A		A0208 ANA AVS CED RH TEMP	LO	TBD	A	2M	MLB/VNB	24/24
131HQ	A	121	N/A		CHASSIS_GND		TBD	A	1M	DR	22
132HQ	A	122	N/A		CHASSIS_GND		TBD	A	2M	DR	22
TBD.GN	TBD	710	TBD				TBD	TBD	1M	DR/AD	24/24
TBD.GN	TBD	710	TBD				TBD	TBD	1M	DR/AD	24/24
3HQ	A	120	TBD				A		1M	DR/AD	24/24
DPWC011		120	N/A						1M	DR/AD	24/24
30HQ		120	TBD						1M	DR/AD	24/24
3HQ	A	120	TBD				B		1M	DR/AD	24/24
3HQ	A	120	TBD				X		1M	DR/AD	24/24
3HQ	A	120	TBD				Z		1M	DR/AD	24/24
DPHQ071		121	N/A						1M	DR/AD	24/24
9WC	A	120	TBD				C2		1M	DR/AD	24/24
									1M	DR/AD	24/24

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APPENDIX 4: List of errors highlighted by the pre-sizing team:

<u>Type/Gauge:</u>
KO: Type gauge is missing
KO: Type gauge is not defined in SSL

<u>Route:</u>
KO: type of route is missing
KO: Type of route is not defined in the TDD

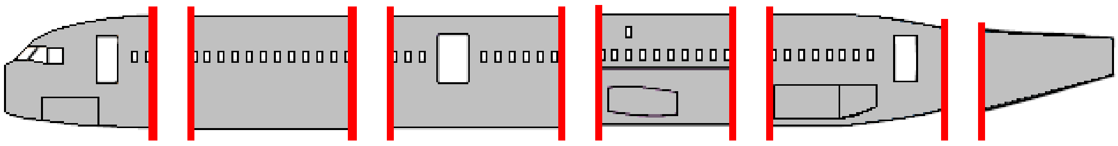
In both cases, an email has to be sent to the SD with the tif attached, and the route/gauge in fault highlighted.

<u>Interface Name:</u>
OK: The interface name is missing or not defined in the database but there is no cross-reference.
OK: If interface name contains “HPP” (Hard Pin Programming)
OK: The interface name is missing, but the item is a FSI. The line name has to be manually written in the CSV.
KO: The interface name is missing and there is a cross reference to another plan
KO: Interface name is not in the Line-Name-Data-Base and there is also a cross reference to another plan

<u>Extremities:</u>
OK: The FIN is defined in the APEDD
OKWR: The FIN is actually a FSI of VUxx.
KO: FIN name is missing
OKWR: WXxx grounding point should be named VN instead of WXxx
KO: FIN is not defined in the APEDD
KO: The functional definition of the FIN is not given or is not exactly the same than in APEDD
KO: The equipment is drawn with dotted lines; this item should not be defined in the CSV.

APPENDIX 5: Saucisson assembly process

The figure below represents the vertical cutting applied to the A320 aircraft. This scenario is also named full barrel or Saucisson scenario.



The two parts are first mechanically assembled according to the procedure below

Alignment of the Fuselage sections,
Drill-Template installation,
Drilling of pilot holes,
Removing one section for cleaning and sealing operations,
Taking the section back,
Drill-Template installation,
Drilling of final size holes,
Bolt installation,
Final sealing application,
Closing of system interfaces.

Then the final assembly (FAL) process is performed. The operations are done linearly and can be separated in 5 major steps:

Mechanical connections of two parts,
Electrical connections,
Others connections (hydraulic, pneumatic...)
Assembly of the VTP/HTP and the wings,
Electrical tests.

APPENDIX 6: State of the art on unrolling harnesses

Long harnesses are already used in current A/Cs. For example, in the A321, there are three harnesses that are between 15 and 20 meters long.

From a technological point of view, there is no limiting factor to manufacture longer harnesses but the usefulness of this technique must be investigated before being industrialized.

Pro's	Con's
Better reliability compared to an equivalent assembly of small harnesses	Modification cost increased
Cheaper / lighter than an equivalent assembly of small harnesses	Recurring Costs increase
Could be used to reduce the number of interface connectors	Harnesses handling and transport

Pro's:

Using long harnesses make them more reliable than an equivalent assembly of smaller harnesses because they don't need any connector from one end to the other. Therefore the risk of bad connection between two sections of cables is suppressed with this technology.

For the same reason, long harnesses are cheaper and lighter because the cost and the weight of the connectors necessary in an assembly of small sections are suppressed. This advantage is valid only for the manufacturing step.

Eventually, one can apply with long harnesses an installation scenario in which, for instance, a 35 meters long harness would be fixed during the MCA process in a long panel central part. This harness would have an extra length of 5 meters for the cockpit that would be unrolled and plugged in equipments inside the nose fuselage (opportunity scenario in replacement of interface plates).

Con's:

On the other hand, the modification cost is increased in the case of a long harness. Indeed, when a maintenance / customization operation is required, the harness must be completely changed whereas it would be locally modified in the case of an addition of small parts. This trade (manufacturing / modification) must be carefully analyzed over the whole A/C life before choosing a solution.

The recurring costs are also increased with long harnesses, as they need bigger plants to be elaborated and stored.

Another limitation is their weight that requires an adequate staff to carry and install them. The number of people to handle a big harness can be deduced from the following chart.

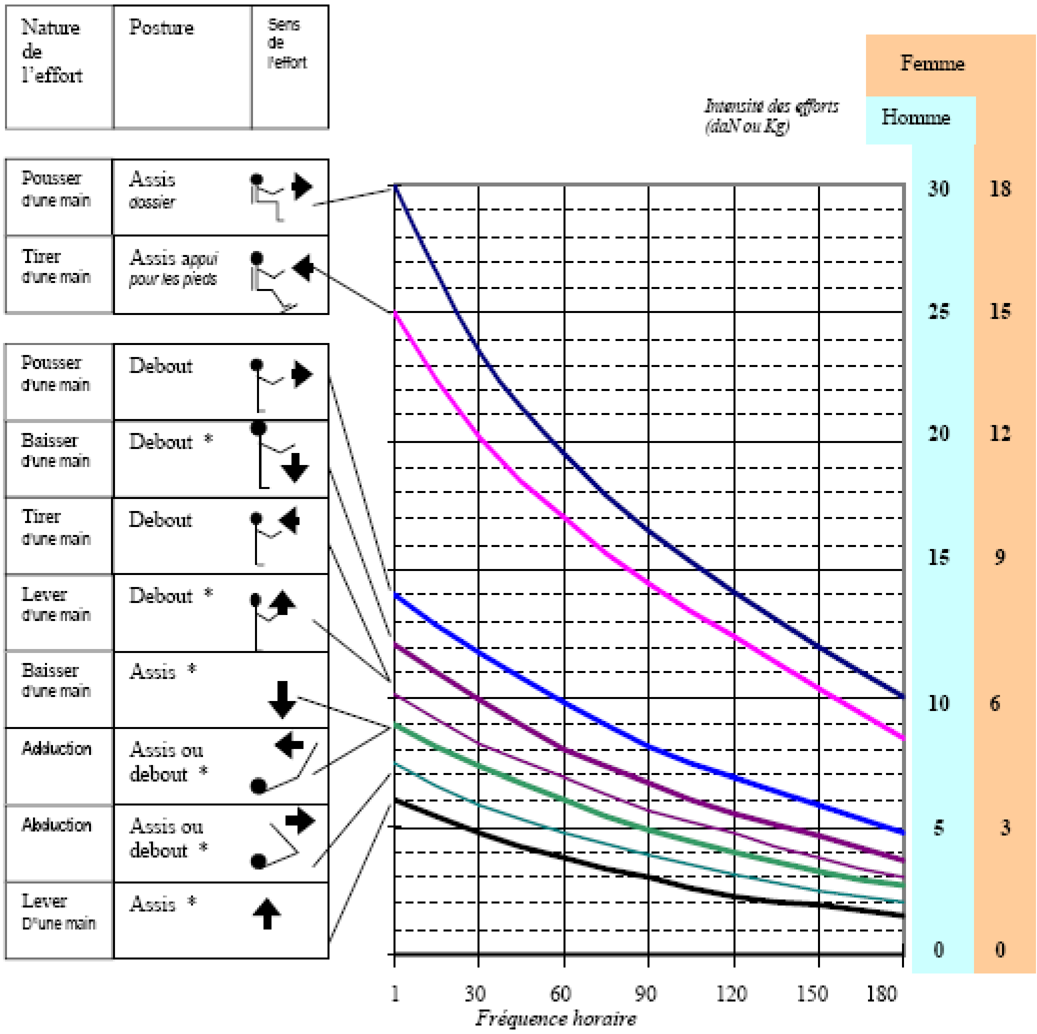


Figure 29: Maximum weight per effort type chart

This graph indicates per effort type and frequency the maximum weight allowed for a man or a woman. For example, if a man must lift a 10kg object, it can do it once per hour. Therefore, per operation and harness type, one will refer to this graph to determine the number of people required to carry on a given installation task.

Concerning the transport, one will have to make sure that there is enough space to place the harness at the right place before starting the installation operations. The roof will also have to be solid and stable to support the harness weight.

To summarize this section, one can say that there is no technological showstopper for unrolling harnesses use but rather ergonomic, economical and organizational ones.