EC175 COMPLEX INTEGRATION CONSIDERATIONS IN ZONAL SAFETY ANALYSIS

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1. ABSTRACT:

The EC175 is a new modern civilian helicopter which embeds complex and highly integrated functions. In this context, Airbus helicopters decided for this new development to implement a new process for zonal safety assessment activities. Mainly, this includes a dedicated safety team, specific organization and a general design recommendations guide.

2. ABBREVIATIONS:

AC	Advisory Circular
ARP	Aerospace Recommended Practice
CMA	Common Mode Analysis
CRI	Certification Review Item
CS	Certification Specification
SSA	System Safety Assessment
ZSA	Zonal Safety Analysis

3. CONTEXT :

Old generation helicopters were quite simple with few electronic/electrical systems; these systems were independent. The Zonal Safety Analyses were therefore quite simple, managed by a limited set of rules, initiated on the first prototypes and mainly based on a check on the final prototype representative of serial helicopter. Few issues were raised by this check, and problems were easily solved.

The EC175 is a new modern civilian helicopter which embeds complex and highly integrated functions. This tends to decrease the amount of computers, and consequently should simplify the integration and ease Zonal Safety Analyses. Nevertheless, the criticalities of equipment are higher, generating more stringent installation constraints. In addition, compared to previous helicopter generations, more functions and more redundancies are implemented to enhance mission reliability and increase safety level largely beyond certification objectives. Finally, the global situation is an increase of the amount of equipment, and an increase of equipment criticality which generate complex installation requirements.

In addition to safety constraints, taking into account maintainability constraints, room for occupants and luggage compartment, the global exercise of Zonal Safety Analysis is more complex than before. The risk of discovering problems late in the development, with high schedule and cost impacts, is not negligible if past methods are applied. Indeed, the check on prototype does not avoid a poor integration considering complex work shares and possible abstract requirements; this implies corrections not easy to perform on a complex helicopter.

4. OBJECTIVES / CONSTRAINT:

The objective is to design a new helicopter with a complex installation, taking into account challenging schedule, cost objectives, constraints from many disciplines and safety objectives. So it is necessary to create a new process adapted to the various objectives.
Usually such an exercise is highly iterative considering the continuous design modifications which result from normal development tuning and addition of new optional equipment which arrive later in the development.
It is necessary to have:

- a methodology which will allow management of adequate zonal aspects, instead of undergoing design modifications. Expected benefits are time saving, better confidence in modification process and right first time.
- a good network between people which permit to catch modifications early and provide recommendations or alerting.

In order to successfully manage this challenge, it was decided to dedicate a specific safety team to be in charge of Zonal Safety Analysis This team started its job at pre-development phase to influence general vehicle architecture choices and was present during the whole development phase.

5. METHODOLOGY:

Our methodology is in spirit of ARP4761 appendix I Zonal Safety Analysis.

5.1. General installation recommendation

According to AC29-2C, equipment installations within each zone of the rotorcraft must be at an adequate safety standard with respect to design and installation standards, interference between systems, and maintenance errors.
In this context, the first step was to update general installation recommendation guidelines based on feedback experience and design expertise. This guide is already used during the pre-development phase before any architecture or design proposal. There are two kinds of recommendations:

- **Design recommendations** provide designers with safety requirements to be considered in the equipment design at the pre-development phase. These requirements will help to reduce possible interaction between systems/equipment installed in a given zone. Indeed thanks to these precautions, equipment failure interaction with neighborhood is limited.

- **Installation recommendations** are also totally part of system design. They must be taken into account during pre-development phase. They are also helpful to ease fulfillment of safety objectives. Nevertheless, the non-respect of a recommendation does not systematically endanger safety objectives.

This guideline was largely distributed and promoted among design teams. The objective was to consider the integration safety constraints early and as a consequence to avoid later redesign. The guide was established early to decrease the risk of having an unsafe installation which would require further costly and time consuming modifications.

List of family recommendations:
Family recommendation list 1 – Ensure segregation of redundancies
Family recommendation list 2 – Mitigate high pressure failure consequences
Family recommendation list 3 – Mitigate high speed rotating parts failure consequences
Family recommendation list 4 – Avoid hot points

Family recommendation list 5 – Ensure safety after cargo fire

…

Figure 1: extract of recommendations list

Ref.	***Recommendations***	***Type***	***Subsystem involved (for info)***	***Possible solutions***
ZONAL RISK				
FAMILY RECOMMANDATIONS LIST 1 - ENSURE SEGREGATION OF REDUNDANCIES				
1.	Redundant lines or components shall not be maintained by the same attachment or on the same mounting	Installation	All	

5.2. Zonal reviews

The helicopter was broken down in zones in order to ease the analysis. Boundaries of a zone usually correspond to a physical separation on the helicopter. These physical separations minimize the risk of effects propagation from one zone to another.

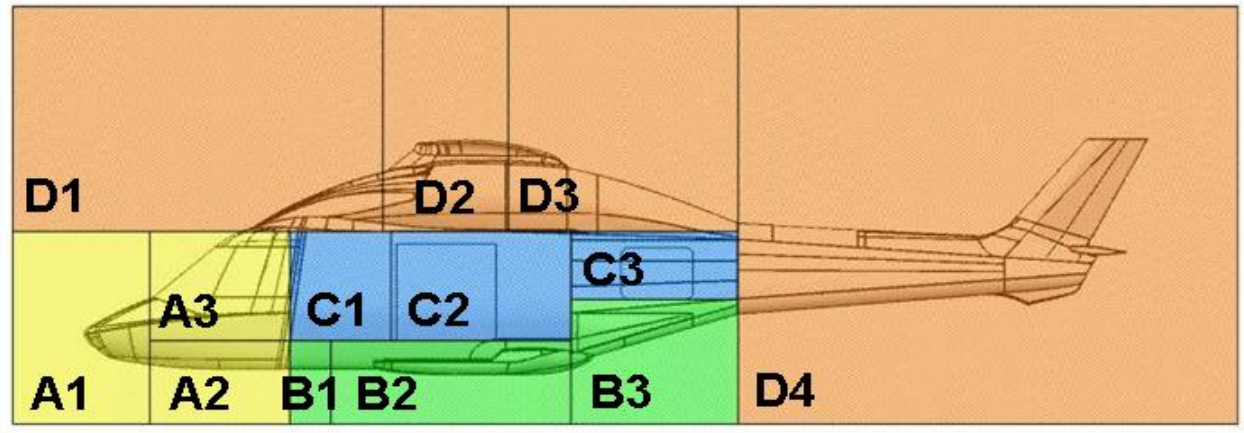


Figure 2: EC175 zonal breakdown

During this second step, the ZSA team started zonal reviews on the digital mock up to check periodically acceptability of each zone and evaluate deviations versus the recommendation guidelines. Acceptability of each zone is established by failure scenario construction; characteristics of failures to be considered are given by designers.

For each zone judged not acceptable, weak points are listed. Strategies to eliminate weak points are deeply analyzed with designers and safety engineers.
Usually these weak points result from the impossibility to apply a point from the recommendation guideline due to high installation constraints.
Despite correct application of the recommendation guideline, it may appear that some scenario in a given zone is not acceptable. In such a case the missing recommendation is identified and added in the guideline.

This periodical monitoring of zones allows improving continuously the installation while the helicopter is still in the virtual world of the mockup. It offers a progressive maturity until situation is frozen to launch prototypes.

5.3. System safety analyses requirements

The third step occurred in parallel to the second; installation requirements associated to equipment were established from system safety analyses and Common Mode Analysis parallel processes and cascaded to the relevant zones.

5.4. Methodology benefits

Having an installation guideline applicable for general purpose and having specific requirements for equipment/zones, it became possible to evaluate the compliance of each zone very early in the development, based on digital mock up.
Then, design modifications had to be made with respect to established rules, and as a second checking net, periodical zone reviews had simply to analyze the delta versus the previous review and evaluate if installation still complied with objectives.
The occasion of first Prototype assembly was the opportunity to consolidate the analysis by direct visual inspection of each zone.
It was also the time to formalize analyses in a global document to create a picture of the Prototype.
This process was then applied to further Prototypes and until certification. Post certification modifications will also follow this method.

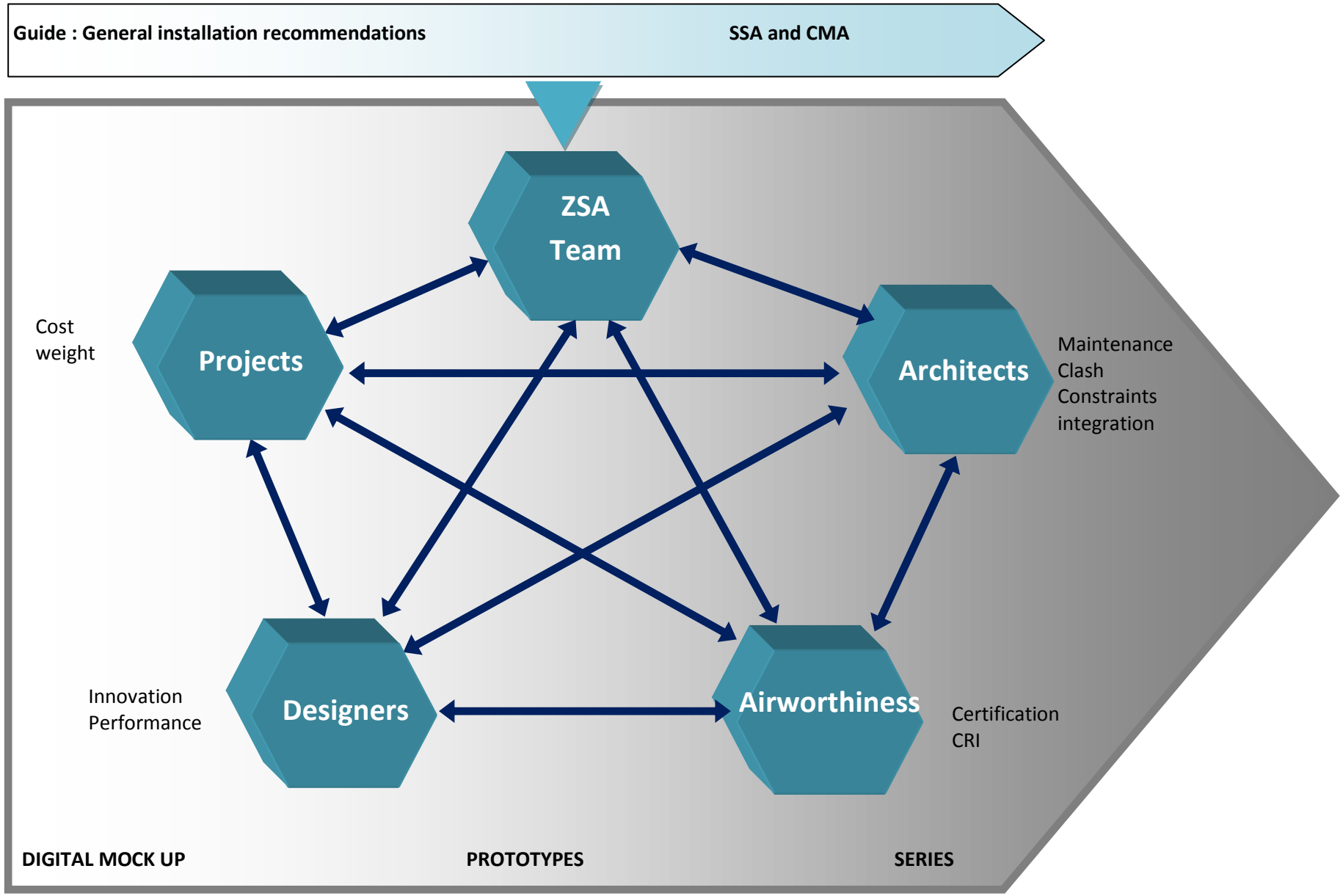
6. ACHIEVED RESULTS:

Despite difficulties in comparing classical Zonal checks near the end of the process, having no reference of a similar development from scratch with such a method, the applied methodology tends toward right first time, which was one of the key objectives.
Some key elements worth mentioning:

6.1. ZSA team

The key difference compared to past development is the decision to create a dedicated ZSA team acting at the very beginning of the development. Objective of this team is to ease connections between safety process and design.

Goal of this team is to anticipate, detect, correct and alert in case of problem. This team is largely interconnected with all stakeholders involved in installation and of course with other safety activities. To save time in the development, this team is also able to advise efficiently about advantages and drawbacks of proposed solutions
To be efficient, ZSA team should be mainly composed of experienced people. When a new member integrates the team, time is necessary to ramp up one's skills on.
ZSA team shall also be able to face designer turnover and make sure that message previously given will be forwarded and applied by the new designers. It is important to have a process strong enough to resist to company re-organization and people turn over, to do so, written recommendations are necessary, as well as training and permanent communication.


Guide : General installation recommendations
SSA and CMA
ZSA
Team
Projects
Architects
Designers
Airworthiness
Cost
weight
Maintenance
Clash
Constraints
integration
Innovation
Performance
Certification
CRI
DIGITAL MOCK UP
PROTOTYPES
SERIES

6.2. Network

This implementation requires the establishment of a mature process between the different stakeholders involved in the helicopter development. The complex system integration is interfaced with multiple actors: architect, designers, project management, airworthiness, etc., with different constraints.

ZSA team has an unfortunate tendency to increase cost and weight contrary to project objectives. The game is to find well-balanced compromises between each participant's needs.
ZSA team has also spread acquired experience towards other projects in order to anticipate solutions on these projects or to provide advanced information. This created strong networking and ease also feedback from other projects toward EC175 ZSA team, enriching all the teams.

In this context, communication is one of the key success factors, and is favored by the plateau.

6.3. Digital mock up VS prototype

This first experience underlines also some points which need specific attention for the next development. Despite a high quality level of digital mock up, minor discrepancies can appear on the prototype; for example electrical harnesses routing may be slightly different because of manual installation constraints. In such a case, ZSA team goes directly on prototype with the architect and the designer to analyze and to find an adequate solution. Reactivity and quick decision are required during such situations.

6.4. Innovation

The general installation recommendation guideline shall be enriched throughout the development to cover unanticipated new scenarios, linked to innovative choices. This shall be done fast, despite occasionally specific tests may be necessary. Some recommendations are created based on theoretical research, meeting with partners, brainstorming and experience. For example, new equipment/technology may be incompatible in specific zones due to associated risks.

6.5. Availability of ZSA team

The architecture is constantly evolving, and ZSA team shall be aware of any evolution to confirm if it is still in line with safety objectives. One of the difficulties is to catch as soon as possible among many evolutions, the modifications which have an impact on safety. To be fully efficient this implies to be aware of modifications before they are in the formal modification loop. Thus it enables to take an immediate decision, avoiding wrong choice and further iterations.
Designers and project can ask ZSA team opinion at any time to prepare modifications or evolutions of the design. This implies anticipation of the ZSA team workload and availability. A minimum of one person of the team shall be able to stop this activity to answer promptly to the request in order to keep a good efficiency.

6.6. Team spirit

It is difficult to formalize the status of each zone at the beginning of the development, considering the high rate of modifications. Therefore a part of the process shall rely on the safety engineer and the potential turn over in the team during this phase may become a problem. Periodical meeting are planned in internal ZSA team to exchange information and open points.

7. CONCLUSION:

The EC175 is the first Airbus Helicopters product which benefits from this process. It is a process which allows safety objectives to be met in an efficient manner. It will be re-applied on the future developments and tools will be developed to save more time and improve efficiency.

8. REFERENCE :

R1 ARP4761 Appendix I – Zonal Safety Analysis (ZSA)
R2 CS 29 Certification Specifications for Large Rotorcraft
R3 AC 29 Advisory circular – Certification of transport category rotorcraft

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