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Methodological Guide to ASIC Design with Durability Management "COCISPER: *Co*nception *C*ircuits *I*ntégrés *S*pécifiques et *Per*ennité"

(September 2000)

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SUMMARY

The military sector is characterised by specific aspects such as small series, high reliability, long life-cycle products. In this context, the DGA wished to set up means to develop specific integrated circuits for the durability of electronic systems.

Thus, in 1995, a first COCISPER contract has been awarded to a Consortium fully representative of the industry in France.

It is aimed to establish a methodology guide for designing ASIC taking into account the needs for system durability. Therefore, it defines an industrial standard following the withdrawal of mil-spec ones.

The guide produced within this project specifies the general development plan of numeric integrated circuits at the ASIC design process level, but also at the equipment and system specification, validation and qualification stages. It proposes recommendations applicable to the whole industry.

A follow-up study has been awarded to the same Consortium in 1998 which aims at experimenting and validating the COCISPER guide on real applications, but also at updating it to take into account the Programmable Logic Devices (PLD) ant recent techniques such as the use of Virtual Components.

In addition, an evolution of the guide facilitating the access to information has been asked. A HMTL version is now developed and available.

INTRODUCTION

Progress in microelectronic technology has allowed the use of increasingly high-performance Application Specific Integrated Circuits (ASIC) for the benefit of systems. However, their use involves problems associated with the particularities of those integrated circuits and also from the characteristics of military and aerospace equipment and systems: Complexity, performance, reliability, cost, harsh environments, limited production lead times and long term availability for the durability of systems.

COCISPER, which stands for "Conception Circuits Intégrés Spécifiques et Pérennité», is firstly the name of a project seeking to draw up a methodological guide to ASIC and PLD designs with a view to ensuring system durability and control of the long term availability attributes surrounding development process. These are the fundamental objectives of the guide.

COCISPER is thus also the name of the industrial Consortium which is entrusted in the realisation of that project, with the support of French DGA. The Consortium comprises representatives of seven defence and aerospace sector companies, leaded by Matra BAe Dynamics, and the partnership of Aérospatiale Matra Missiles, Astrium, Sagem.SA, Thomson-CSF Detexis, Thomson-CSF Sextant, Thomson-CSF TTM.

Project objective is to pool experience and methods over a sufficiently broad industrial base to produce the operational recommendations, outline procedures and generic procedures forming the guide. They are based on the best methodological practice (state-of-the-art) to emerge from the sharing of experience and joint formulation of the new recommendations.

The guide is drawn up by industry, for industry. It is an operational guide: It is neither an imposed framework nor an additional constraint. On the contrary, it should enable everyone to develop their own procedures consistent with in-house development references. Depending on the nature of the requirements, the guide may concern system manufacturers, equipment manufacturers, in-house ASIC functions or design centres providing services, supply and production functions and contractors in development (CAD and software tool suppliers, founders).

COCISPER also wants to take advantage of the new quality assurance approaches developed in the electronics industry and thereby to promote, through the methodological guide, changes in practice. For example:

- Specify requirements first, not solutions;
- Define and characterise processes;

Paper presented at the RTO SCI Symposium on "Strategies to Mitigate Obsolescence in Defense Systems Using Commercial Components", held in Budapest, Hungary, 23-25 October 2000, and published in RTO MP-072.

- Do not wait for the final result before measuring how appropriate they are;
- Validate and react: do not consider the prototype to be the end of the project's life cycle…

OBJECTIVES OF THE GUIDE

However, their use involves problems associated with the particularities of those integrated circuits: performance, cost, low production volume, lead times, etc. These constraints arise also from the characteristics of military and aerospace equipment and systems: complexity, performance, reliability, harsh environments, limited production and durability.

As previously said, durability is, at this time, one of the main issue for military and aerospace equipment and systems. Contemplating system durability at ASIC level will mean either ensuring durability of the integrated circuit or maintaining the ASIC function at card level throughout the life cycle of the system.

In this context, COCISPER's objective is to draw up a generic development plan applicable to digital ASIC. It takes account of durability requirements at system level, development quality, and control of economic conditions. The flexibility essential to industrial competitivity is taken into account in those objectives.

Given that such a guide must command broad acceptance and be validated in real situations, the approach to drafting the COCISPER recommendations is based on the following objectives:

- to create conditions for acceptance of the guide outside COCISPER by targeting all potential users of the methodology, including civil industry;
- to validate application of the recommendations in practical experiments with ASIC development;
- to involve microelectronics educational and training institutes in order to evaluate how COCISPER's work can be used to assist training in the methodology of ASIC design.

This determination to interact with the players in the ASIC community must make this guide a living tool, capable of adaptation to the markets targeted and to developments in technology or the state-of-the-art. The work remains compatible with existing standards (e.g. ISO 9000) and does not, in any way, represent an additional constraint.

SCOPE OF THE GUIDE

It is illustrated in figure 1. The COCISPER methodological guide sets out to answer a number of methodological questions facing the ASIC designer and user community both from the technical point of view and from the practical and economic points of view.

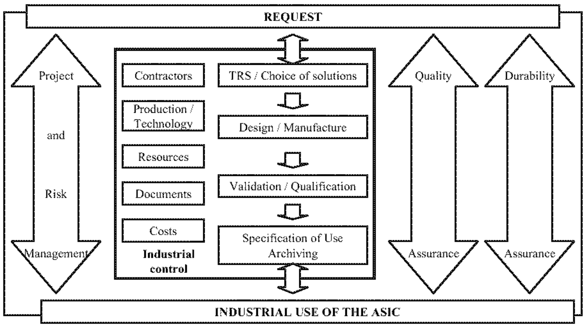

Figure 1 : Scope of the guide

From the technical standpoint, this methodological guide deals with all the points necessary to produce an ASIC, from the request made by the user to industrial use of the ASIC. It is constructed around the ASIC development cycle.

It takes account of all the problems associated with industrial control of that development cycle and the associated methodological support, laying particular emphasis on peculiarities specific to the ASIC. It identifies as clearly as possible the parameters that tend to degrade service and ultimate quality, giving recommendations regarding:

- the control of contractors,
- the process,
- the manufacturer,
- the tools,
- the documentation,
- and the costs.

In the context of the methodological support, it sets out all the aspects necessary to the smooth running of the whole project, such as quality assurance, durability assurance and of course project and risk management, for the ASIC is above all part of a project.

From the practical standpoint, this guide is directed at all those who come into close or remote contact with ASIC. To that end it offers a set of recommendations and information about its use, its specific vocabulary and mode of evolution.

THE GUIDE: CONTENT

The guide concerns a field, which may be summarised as follows:

- **Development flow**: Technical Requirement Specification (TRS), choice of solution, description of the functional design stages through to the physical design stages, specification of the interfaces with the founders and CAD tool suppliers, validation of prototypes, qualification of the ASIC for use, specification of use, and supply specification;
- **Support methods and activities**: ASIC activity management, ASIC project management, quality

management and quality assurance, durability management and assurance, quality control and industrial control, documentation management and industrial use of the ASIC.

Under those headings, the guide describes the flow of ASIC design - that is the operational view of development - and the methods used to manage and control that flow - they are the process support activities.

The Technical Requirement Specifications (TRS)

Two essential tasks must be performed before launching the design of an ASIC:

- drafting of the TRS
- a feasibility study and choice of solutions.

The TRS is a reference document in which the requester and the designer of an ASIC agree on the characteristics of the product. The TRS is consistent with the functional specification. It differs from the latter in that the functional specification expresses the requester's desires without ensuring that they are realisable under the prevailing technical and economic conditions. In the case of the TRS, the requester makes a commitment regarding his requirements and the associated constraints, and the designer a commitment regarding his ability to undertake development of the circuit with a guarantee of success. To this end, the TRS must state:

- the functional requirements and the environment conditions;
- the dependability requirements;
- the interface requirements;
- the design and production requirements;
- the product qualification and acceptance requirements;
- the conditions regarding verification of compliance with the requirements.

The TRS is a contract binding the customer and the supplier.

The feasibility phase (analysis of the requirement, exploration of concepts, etc) and definition phase (choice of concept and specification of requirements) must culminate in a first reference version of the TRS usable by the designer. Nevertheless, it would be a mistake to think that those involved in these (necessarily short but not too short) preliminary phases can grasp all the implications associated with implementation of a function in a circuit. It is therefore highly probable that this TRS will evolve during the design work. The whole problem is therefore to put in place solutions, which can control the changes as well as possible in order to maintain consistency with the initial definition on which the design centre embarked.

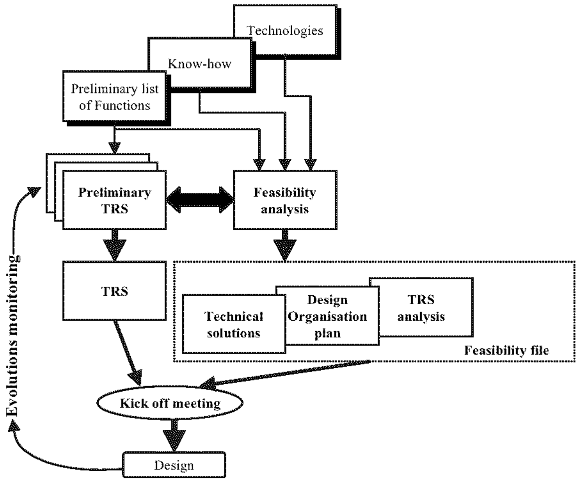

Figure 2: TRS and feasibility analysis

The Design and Prototype manufacture

The standard flow suggested in the figure 3 includes two successive phases entitled design and manufacture respectively. It is applicable in broad outline to all types of ASIC, including programmable ones, subject to a few adaptations such as, for instance, the elimination of certain tasks, or their replacement by other dedicated to PLD.

The design phase divides into three stages, namely, in chronological order of execution:

- preliminary design,
- structural design,
- physical design.

Owing to the strong interactions between preliminary design and structural design, these first two design stages are not always treated separately in practice. As a result, no precise formalism at their common interface is defined.

The manufacture phase described relates solely to mask-defined ASIC. In the case of PLD, this phase is either deleted (this is the case with circuits programmed in the application) or replaced by programming by means of a dedicated device.

Every phase yields elements in conformity with the input documents, which have, themselves, been validated. The information in the TRS is assumed to have been validated vis-à-vis the system. Consequently, the validation operations performed during design are intended solely to ensure that the various descriptions of the ASIC conform to the requirement stated in the TRS. Similarly, the various tests performed on the component during the manufacturing process serve only to ensure conformity with the software model resulting from the design process.

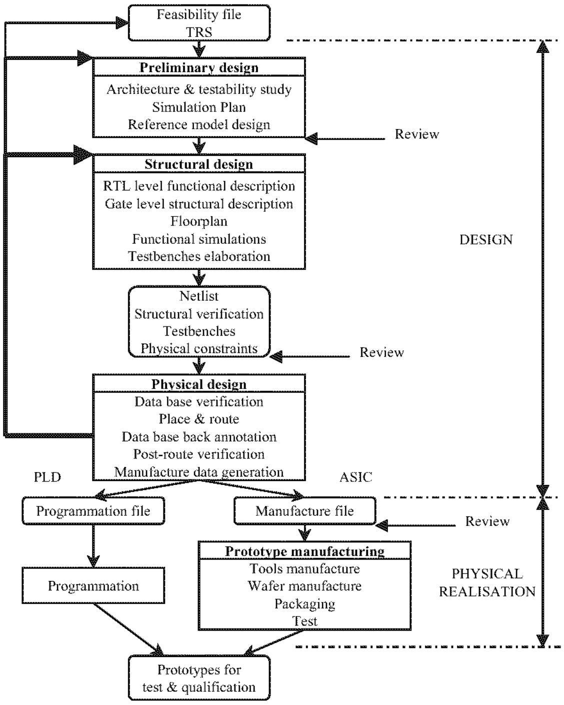

Figure 3: Design and prototype block diagram

The Validation

The Validation phase is part of the general ASIC design flow. The status of "validated ASIC" is acquired when all the requirements listed in the TRS are fully satisfied:

- relatively to the virtual product, by using simulation techniques,
- relatively to the real product, through an overall validation process.

It allows checking the complete match between both virtual and real products. However, the founder must qualify the technology, the manufacture process and the libraries.

The virtual product is the result of the structural design phase. It includes a structural netlist *but also* the associated test vectors.

The real product is the result of the manufacture phase. In the guide, this chapter only covers its validation. The verification of the virtual product is fully described in the chapter of the design phase as it is usually performed by designers or by a specialised team closed to the designers one.

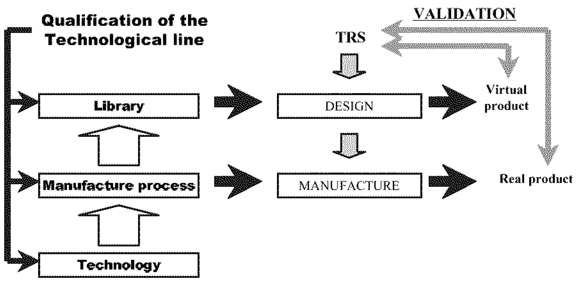

Figure 4: Localisation of the Validation

Industrial control issues

The development process consists of a number of stages leading to the supply of ASIC that meet the requester's requirements. If the development's industrial environment is well controlled, development may be linear and culminate in the expected result. Experience shows that the process is disrupted by external factors inherent in the industrial development environment. The "Development process control" sets out ways of controlling that process.

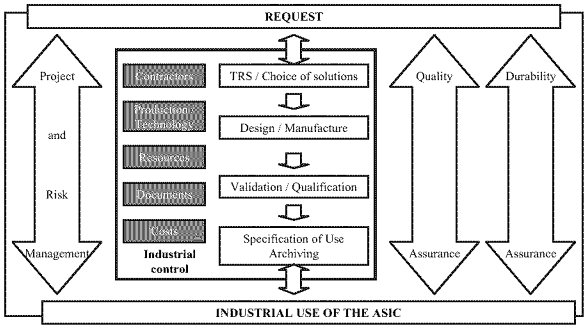

Figure 5: Scope of the Industrial Control

The shaded boxes in the figure 5 indicate the scope of industrial control in relation to the scope of the guide as a whole.

Control of contractors is based on the principle that the development of ASIC involves a succession of complementary specialities. Those may be found within the industrial firm developing the ASIC or among its contractors. To ensure proper control of them, a dynamic mode of interfacing must be established between the industrial firm and its contractors, based firstly on principles common to all the specialities and secondly on particularities of certain specific fields of activity. The specialities are grouped around four main areas of activity:

- design,
- analysis / characterisation,
- manufacture,
- and tools / libraries.

Control of the production technology and the founder represents an unavoidable special case in the development of ASIC. The methodology is based on general control of manufacturers, which relies on consolidation of the aspects of quality assurance applied by the manufacturer:

- generic qualification of combinations of manufacturer and production technologies,
- the establishment of quality contracts between the manufacturer and the industrial firm which is developing the ASIC.

This is to take place in a context separated from the projects, but obviously before they need any support from the founders. At this point, it should be emphasised that the ASIC designers have to get into contact with them as soon as possible, that is at the beginning of the design phase in order to make sure the design will be fully compliant with any founders' rules. It also means that any internal procedure must be soft enough to allow this adaptation, and some design rules must be set up to assure portability from one technology to another one.

Control of resources centres on two main categories used during development of ASIC: CAD tools, and test resources specific to ASIC. In the case of the CAD tools, the specific aspects of those that are technology-independent and those that are dependent on a particular technology are identified. As control of these tools is particularly critical to ASIC development, a number of provisions designed to limit the risks they generate are presented in the guide.

Project management

The lifetime of a system is the period covering the system's development, refinement, production engineering, production, delivery and maintenance.

During the system's life cycle, ASIC project management traditionally covers development of the ASIC, from specification of the circuit (on the basis of the system specification) to delivery, validation and qualification of the prototypes.

To a lesser extent it also covers the system-refinement and production-engineering phases (through the production engineering of the system's components).

The need to take account of long-term durability problems, as well as developments in technology and design techniques naturally means that ASIC project management has implications for and is affected by the equipment production and maintenance phases.

That is why the Consortium has chosen to put into perspective the areas of concern of ASIC design team leaders wishing to develop their activities towards improving the service provided for the users.

First of all, in the light of the "system" or "programme" view of project management, we shall define more clearly the relationship between ASIC development and the requesters' needs in terms of visibility and assurance of the smooth running of the project. This will lead us to define the modes of interfacing between a project team and an in-house or external ASIC design centre.

Therefore, a precise distinction is to be made between the terms:

- "ASIC project management", which designates the management of a team designing application-specific integrated circuits,
- "project management", which designates management of the user or requester projects. The term "requester project" should be understood here to mean the project in the context of which one or more ASIC are being developed.

In addition, the Project Manager will also have to assure:

- the relation with Purchase managers and suppliers, in particular the founder and tools providers to get the necessary information on they strategy
- the relation with the human resources. This point is one of the most important as the consequences of any decision have short but also long term impacts
- the promotion of the technology.

Also, the Project Management is involved during the BID proposals.

According to the organisation of the company, one or several people can handle all these aspects.

Accommodation of Risks

ASIC technology is often associated with a high notion of risk… This issue, however, can be addressed at the design level, but also by applying a rigorous project management.

ASIC development plan: Management - ie. Minimisation - of the risk associated with design necessitates, ideally, keeping development within the strict framework of the team's area of know-how. However, this principle frequently conflicts with the need to adapt that area to respond to new requirements or to apply new techniques if these alone will allow the planned circuit to be constructed. At all events, the risks associated with the particular situation of the ASIC contemplated must be identified, so that the specific actions to minimise those involved in development of the ASIC can be defined. Such analysis is necessary to lay down and refine the development plan.

Impact on cost: The general principle of risk management in an industrial context is to compare the potential cost of the setbacks that may be suffered as a result of the identified risks with the cost of specific actions to cover them. One also has to estimate the probability of the event feared occurring and the presumed effectiveness of the specific action envisaged to avoid the setbacks. These estimates are generally not strictly quantifiable and must be based on past experience.

To illustrate this principle, the quantity of work involved in validating the design before it is sent to the founder must be measured against the cost and impact on lead times of re-manufacture, which would be necessary in the event of an error. In the case of PLD, the absence of specific manufacturing limits this risk.

Impact on schedule: Besides the frequently direct and considerable impact of not keeping to the design schedule on the development cost of the product using the ASIC, other indirect and equally substantial impacts may be attributed to poorly controlled design time:

- reduced profitability of the project through late introduction of the product and delayed return on investment;
- in a competitive situation, loss of market share, or more directly the penalties incurred in the case of a pre-existing order;
- loss of credibility…

Ensuring the deadline is met is thus a specific action, and the scale of the effort devoted to it should be proportionate to the risk. The risk is all the greater, as the ASIC is frequently, by its very nature, in the critical path of the project that commissions it.

The difficulty of this task arises from the enforceability of all the hazards that may upset the smooth progress of design, particularly in a rapidly changing technical field. In addition, there is extensive dependency on third parties (founders, CAD tool suppliers, etc), that limits the total control of timing.

Impact on feasibility: The risk of discovering belatedly a problem that calls into question the very feasibility of the intended function must not be underestimated. Its impact on cost and timing is direct and serious. That is why the feasibility study must be conducted carefully and must culminate in both a TRS and a technical solution including a development plan, which must be fully consistent with one another. Experience is therefore crucial during feasibility analysis.

Quality and Durability assurance

Quality assurance: The description of the process of developing an ASIC incorporates activities contributing to ASIC quality assurance, i.e. primarily helping to confer appropriate confidence that the ASIC will meet the requester's requirements. These activities are those which are fully integrated with current development practices and which it would have been artificial to separate from the other stages of development. Examples include simulation activities, design rules verification, etc. The process itself as defined in the guide thus already has a quality assurance dimension.

Other major topics are also important in the context of ASIC, such as industrial control.

Durability assurance: Obsolescence in ASIC is a constant concern for industrial firms, as technologies come to the end of their lives and others no longer meet the economic criteria of the market. Manufacturers are obliged to rationalise their means of production to increase their profitability. The longer the period over which the equipment concerned is produced and maintained, the more critical this context becomes. In particular, the slightest change in the ASIC or the definition of the item of equipment necessitates a qualification process, which is often long and costly.

A set of coherent recommendations constituting a method of ensuring the durability of an ASIC function can be proposed. By "function", we mean a combination of functional behaviour and performance. The method relies on two essential levers controlled by the industrial firm: the choice of solutions and the design. The object is to ensure that the customer continues to have available a system meeting a requirement, rather than a system complying with a definition.

This concept of durability of function is essential to the control of ASIC durability. It forms part of a customer / supplier relationship based on a commitment as to results and on definition of requirements arising from needs at each level of complexity of the system, down to component level. In particular, a durability strategy cannot be conceived independently of the rest of the system. It must be the product of a system durability strategy deployed at component level.

Durability assurance has two aspects:

- Preventive action to ensure durability of function: This forms part of the initial development of the ASIC and can be described as a set of applicable recommendations to facilitate re-design of the ASIC and maintenance of its qualification.
- Action to deal with component obsolescence to make sure that a solution is available to ensure system durability.

It may be noted that the durability of an ASIC is highly dependent on the manufacturer's ability to ensure durability of the production technology, i.e. that of the component and the function. The same is true of the choice of solutions presented above as one of the levers essential to achievement of durability.

Relationship between Quality and Durability assurance: Quality assurance may be considered to encompass all the steps taken to ensure control of the development process and the achievement of a solution satisfying the customer's requirement. One could define its ultimate objective as fitness of the solution for the purpose. As a complement to that, durability assurance may be defined as all the steps taken to ensure the availability of solutions, at a controlled cost and within a controlled time, that satisfy the customer's technical requirement throughout the life cycle of the function. The ultimate objective in this case is the availability of suitable solutions.

The figure 6 illustrates this principle. For a given ASIC, the shaded area represents the provisions to be put into effect, with no regard for durability requirements. The upper curve indicates the provisions to be put into effect to cover all the requirements, including durability.

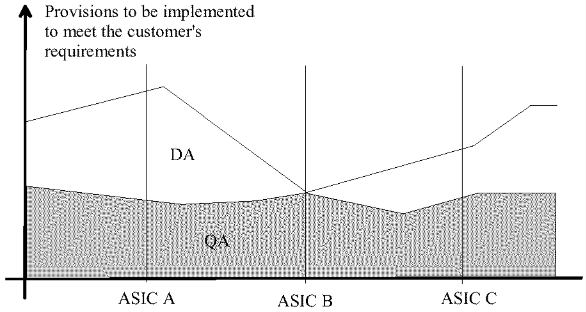

Figure 6: Quality assurance vs. durability assurance

The scope of the provisions depends to a large degree on the requirements relating to the life cycle of the ASIC in question. In the figure 6, ASIC A corresponds typically to a long life cycle (an armament programme, for example), ASIC B to a short life cycle (with no durability constraints), and ASIC C to an intermediate life cycle.

Insofar as availability of solutions that meet the technical requirement is itself one of the customer's requirements, durability assurance could be considered as a facet of quality assurance. However, as durability assurance is a relatively new concept and constitutes one of the guide's major concerns, it has been identified and dealt with separately.

THE HTML VERSION

The HTML release has been organised in such a way that the main topics are directly accessible from the Welcome page, as shown on figure 7.

Guidelines related to quality assurance and durability assurance are integrated and available directly inside the ASIC design process flow with the help of following icons AQ et AP. Recommendations dedicated to programmable logic devices are accessible with PLD.

Therefore, it allows anyone to address directly one (or several) question(s) without the needs of searching through a complex process. However, it remains possible to exploit the guide in a very linear classical way, using the guide table of content.

CONCLUSION - DEPLOYEMENT

Given that such a guide must command broad acceptance and be validated in real situations, the approach to drafting the COCISPER recommendations is based on adhesion through utilisation.

The determination to interact with the players in the ASIC community must make this guide a living tool, capable of adaptation to the markets targeted and to developments in technology or the state-of-the-art. The work remains compatible with existing standards (e.g. ISO 9000 / AQAP100) and does not in any way represent an additional constraint.

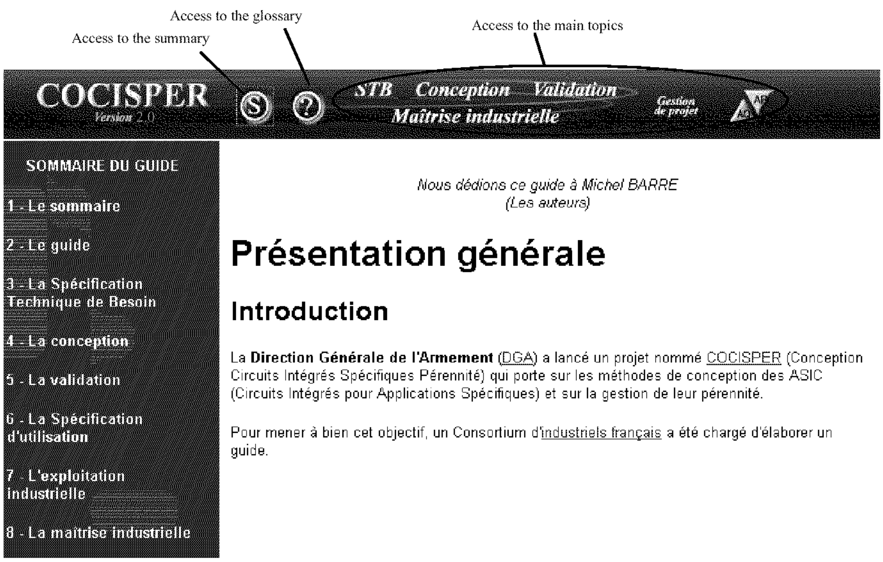

Figure 7: COCIPSER: The Guide – Welcome page

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