# New methodology of work with concurrent engineering in electronic design

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## ABSTRACT

This paper aims at proposing a new enhanced way of working in electronic design. In fact, the design of an electronic component requires many competencies and skills, and the joint effort of several researchers and engineers, not necessarily located at the same place. With traditional ways of work and communication tools, the interactivity level is reduced and it seems that the product life cycle cannot be improved significantly anymore. As a response, the technological progress in high speed networks and new communication and interaction tools open the way to concurrent engineering. This paper then aims at presenting such way of working, the new functionalities provided to users, and of course the benefits they can gain. As a case study, an actual example in the domain of electronics design illustrates this paper.

**Keywords:** Concurrent engineering, Cooperative work in electronic CAD, Collaboration tools, Communication networks

## 1. INTRODUCTION

What is the product that can, nowadays, be designed, developed, made and sold by a single person? In fact, in every activity domain, for every product or service to provide is the result of the work of a complete team that are often geographically distributed worldwide.
This is the case, for instance, in the domains of aeronautical design, and automotive industry. Today, to solve the problem of the multi-disciplinarity skills required, automotive and aeronautical manufacturers create platforms composed by all the people involved on the project, belonging to all the involved manufacturers and suppliers, in a single place. Of course these platforms induce all the problems of buildings, confidentiality, and travels of people. This statement has been the source of a lot of efforts in of concurrent engineering in many economical domains, and lead to the deployment of many intra and extranets. Thus, first work deals with asynchronous tele-engineering (in deferred time), based on electronic mail, file transfers, etc.
But, following that way, synchronous cooperative working is now possible thanks to new information and communication technologies (networks services, computers, multimedia devices, communication and cooperation software, etc.). This new way of working will allow creating virtual platforms or virtual enterprises. It is then expected to improve competitiveness of enterprises in allowing engineers and technicians to increase and improve the number and quality of their interactions. Then, it should be possible to improve the QCD factor (Quality / Cost / Delay) of products.

This paper deals with an experiment of concurrent engineering design in the domain of electronic CAD. This experiment, lead at LAAS, is the first experiment of a larger project aiming at widely deploying such methods of work for all the LAAS research teams in microelectronics, and to improve the relationships between research teams in microelectronics, microsystems and networking. However, this project is at its early beginning. Thus, this paper is composed as follows: first, the framework of the experiment is described: it has been chosen to experience concurrent engineering methodology of work on the thermal analysis of an IGBT (for Insulated Gate Bipolar Transistor) component (section 2). Then section 3 presents the capabilities of the concurrent engineering platform, describes the experiment and section 4 details results of the experiment and a list of limitations. Then section 5 introduces related work and, finally, section 6 concludes this paper.

## 2. CURRENT WAYS OF WORKING IN ELECTRONIC DESIGN

### 1. Problematic of joint electronic CAD

After interviewing and observing engineers and researchers in microelectronics and microsystems, it appears that they mainly use two kinds of tools:

- CAD tools (in mechanics, optics, electrics, electronics, etc.) and simulators of the designed systems; these software tools are related to specific domains;
- Non specific software, as drawing tools, curves generators, screen grabbers, etc. that allows the representation of microelectronic components, but with no formalism and no simulation or validation methods.

On the other hand, many schemas and drawings are still hand made on a classical sheet of paper.

Concerning the whole conception of a microsystem, when engineers and researchers have to put together their own works and results (eventually in different domains), they generally interact during meetings or thanks to the use of communication tools as phone, fax or electronic mail.
During meetings, participants generally use slides or posters. These slides / posters are usually screen copies of a CAD or simulation tool, or schemas or curves generated by informal tools, or hand made. Depending on remarks made during the meeting, modifications can be decided, and they have to be applied on the formal or informal original model after the meeting.
When researchers and/or engineers are distant, they communicate thanks to phone or e-mail, but also with the help of a technical document. This document can be a paper (as a screen copy for instance) transmitted by fax, or an electronic document transmitted as an attached piece in an e-mail. In case of modifications, they are asynchronously made, when the phone or electronic tele-meeting is complete.

What characterises these interaction principles, and put forward their limitations, is certainly the large amount of time between collaborative modifications decision and their application to the electronic models (asynchronous applications), whereas these interactions are typically synchronous (i.e. they have to be applied to the model as soon as decided), and require the simultaneous activity of designers.
As a consequence, important benefits (in terms of design time, and maybe also quality) can be gained by using new communication tools for concurrent engineering as videoconference, electronic distributed white boards (allowing the real time transmission of electronic component modifications or remarks), application sharing tool (allowing the collaborative design, in real time, of models achieved using formal CAD tools), etc.
That is why the remainder of this paper aims at presenting how concurrent engineering methods and tools can be applied to electronic design domain. As a case study, it has been applied for the design of an IGBT component.

### 2. Case of an IGBT design

As an example, it has been chosen to illustrate the benefits of collaborative engineering in the domain of electronics design with a topic out of the research project (RAPSDRA: Reliability of Advanced high Power Semiconductor Devices for Railway traction Applications[1]) where LAAS was involved. The latter topic deals with simulating the thermal behaviour of high power IGBT modules for railway traction applications. This study aims at calculating the temperature and heat flows distribution in IGBT modules consisting of 36 silicon chips. The power dissipation of individual chips has been computed using the SABER CAD tool and the computation of temperature and heat flows distributions have made using the LAASTHERM software [2] [3]. LAASTHERM has been designed and developed at LAAS in order to perform fast thermal analysis and design of complex hybrid power circuits.

[1] Many academic and industrial partners are involved in this project. It is important to note that all these partners are geographically distributed everywhere in Europe.

# 3. THE CONCURRENT ENGINEERING CAPABILITIES

## 1. Concurrent engineering functionalities provided

First cooperative working environments to appear were devoted to asynchronous distributed work and integrate under a unified interface communication tools as textual or multimedia electronic mail, file transfers, distributed databases retrieval, etc. These environments for cooperative working appeared with the development of the Internet and provide, nowadays, services that seem mandatory in our daily work. However, even if they provide users with powerful communication tools, they also have many lacks, as they only allow deferred interactions; then, users do not directly interact: they act alternatively, slowing down the interactions compared to what they could be if people work face to face. Moreover, these asynchronous tools limit the communication capabilities, as they do not allow users to communicate with informal communication supports (as voice for example) that provide nevertheless plenty of information. Phone is often used as a substitute service, but it does not provide a suited solution, as voice is not correlated to the formal information support. It then fully justifies the use of an integrated environment.

However, it is currently accepted that, in addition of these environments for asynchronous cooperative work, it is required to use synchronous services, if possible included in the same general working environment presented above. Currently, synchronous cooperative working environments provide communication and cooperation mechanisms that make possible for users to jointly and interactively act on formal or informal design tools. For that, the cooperative working environment consists of the following main tools:

- Videoconferencing tool allowing vocal and visual communication between two or a larger group of users;
- Distributed electronic white board that emulates the classical white or black board of classical meeting rooms. It represents an electronic support for writing, drawing or presenting slides. In addition, this type of tool is generally enriched with new functionalities as the ability to load electronic models produced by CAD tools for example; it then enriches the range of discussion supports;
- Application sharing tool that are essential in this kind of environments. These tools allow users to share software, as CAD tools for instance, with other participants of the cooperative work session. Thus, application sharing tool allows the sending in real time of the image of the shared application towards all the other participants, that can see in real time the application evolutions, the cursor movements, etc. Sharing tool also allows distant participants to remotely act on the shared application as if the application was run locally. And in the same way, all the other participants can see the remote user actions. Moreover, application-sharing tools provide a high security level as no of the CAD application nor the model data is transmitted on the network. Application sharing tools only transmit display information what forbids hackers to recover the original model.

Other tools can be part of a cooperative working environment as shared workspaces, 2D or 3D distributed viewers, etc. On the other hand, several tools are required as the collaborative work is often performed between more than 2 users. Thus, some organisation tools are required as:

- Workflow management systems that control data exchange with respect to the define business process;
- Group management tools to control the participation of members in the different work sessions;
- Coordination services that allow the mapping between communication services and application requirements.

## 2. Network requirements

Such cooperative work environments have strong and specific requirements. Besides, the emergence of these new ways of working are due to the recent communication networks evolution with an increase of throughput provided and new services arrival.

Historically, distributed cooperative work appeared in early 90s on ISDN[2] networks, that provides users with a guaranteed QoS, even if its flexibility is poor, and if the throughput is quite limited for high quality communication tools. Rapidly, these cooperative work environments have been developed for the Internet that provides more flexibility than ISDN, and that can be easily integrated with the asynchronous communication tools used in companies. Nevertheless, throughputs remain low, forbidding high quality communications, and above all, QoS was no more guaranteed. It is then possible that a work session stops because of a lack of bandwidth. Moreover, with the current massive use of the Internet, the network is very often overloaded, and synchronous communication applications cannot really use the Internet.

[2] ISDN: Integrated Services Digital Networks.

Cooperative work has then been developed over intranets or extranets of large companies. In fact, these companies often owns (or rent) an internal network that interconnects all their research and production sites, on which traffics are perfectly controlled, thus avoiding congestion problems often met on the Internet. On the other side, most of these intranets (interconnecting widely distributed sites) are Frame Relay networks that offer enough bandwidth (generally around 2 Megabits/s) and as a consequence a good QoS for synchronous cooperative work. It is similar for extranets between several companies cooperating in joint projects that can rent Frame Relay links or more often now ATM VP. On such networks providing high throughputs and no congestion (thus a good QoS), distributed cooperative work has known an important development.

QoS remains an essential feature for the development and deployment of these new ways of working. In fact, cooperative working environments generate three kinds of streams – voice, video and data – that have very different characteristics and requirements. For example, voice requires an almost fully reliable connection, with always the low speed throughput. Video requires a variable high speed connection, but with a reduced reliability. Finally, requirements in terms of throughput for data communication depend on users activity, but reliability has to be guaranteed.

Given all these requirements for information communications, it is important to note that one of the main current problems of networks is due to the mutual perturbation that appears between the three kinds of information streams of a single work session. Thus, bursty data streams disturb the temporal scheduling of audio and video information. Solutions that seems to be able to solve this problem are based on guaranteed classes of services for data connections, depending on the information media types: thus audio, video and data can take advantage of different services guarantying the specific requirements of each media stream. Such classes of services exists for some kinds of networks as ATM for example, and are still under development for the Internet: on the Internet, the solution is called DiffServ for Differentiated services, and should be the basis for the next generation Internet (also called Internet 2).

## 2. Experiment with the IGBT component design

As an illustration, a cooperative working environment has been used to evaluate a new IGBT module, and particularly to perform a thermal analysis of this component. Then, distributed work sessions between 3 users took place for duration never longer than one hour. During these work sessions, 3 kinds of interactions appeared:

- The first kind (design phase) consists in showing to all participants a digital picture of the IGBT component. This is performed thanks to the white board tool, the dialog being transmitted with the videoconference. Other participants can then see the component image and all the cursor movements, synchronised with the vocal explanations. In a reverse way, the videoconferencing tool can serve for participants to ask questions, make comments and / or propose modifications;
- The second case corresponds to a formal study phase involving SABER. SABER is synchronously (i.e. in real time) shared between all participants. They can then follow all the actions that are performed on the CAD tool and on the electronic model, but can also remotely act on the shared application (SABER), even if they do not own SABER (i.e. this application being run on another distant workstation). Moreover, confidentiality and privacy are ensured with application sharing tools as the application and the data are not transmitted on the network. In addition, as in the first case, participants can informally comment their actions using the videoconferencing tool;
- The third case corresponds to the acceptance phase. In this phase, participants use informal generic tools as Spyglass-TRANSFORM (to present the results of the thermal analysis performed with LAASTHERM) and Matlab (as a 3D curves generator). These tools are shared in the same way SABER was in second phase, allowing users to follow all the results and all the movements and rotations on 3D curves displayed, and of course the videoconferencing tool allows them to vocally communicate.

To illustrate this experiment, Figure 1 presents a design session, using SABER, between 3 partners geographically distributed and interconnected thanks to a communication network providing enough bandwidth and a suited quality of service. This network can be an intranet (inside a single organisation), an extranet (between two organisations closely collaborating) or a public Internet (of second generation). This schema shows the information streams between the 3 partners:

- IGBT information broadcast from Partner #1 to other partners thanks to the white board;

- Graphical events of the SABER CAD tool broadcast in the same way as IGBT information. It is however to notice that SABER models and data are always located on the Partner#1's database, and that these data are never transmitted on the network for confidentiality and security reasons. Only the graphic images are transmitted on the network : partners #2and #3 only get the image of the screen of the original application. Nevertheless, they can remotely act on the SABER application running on the partner #1's workstation;
- Audio and video streams of the videoconferencing tool, emulating face to face dialog between partners.

Then, Figure 2 presents a screen copy of this experiment where all the elements of this scenario appear: the videoconferencing tool, the white board broadcasting IGBT information, the SABER sharing and the session control tool.

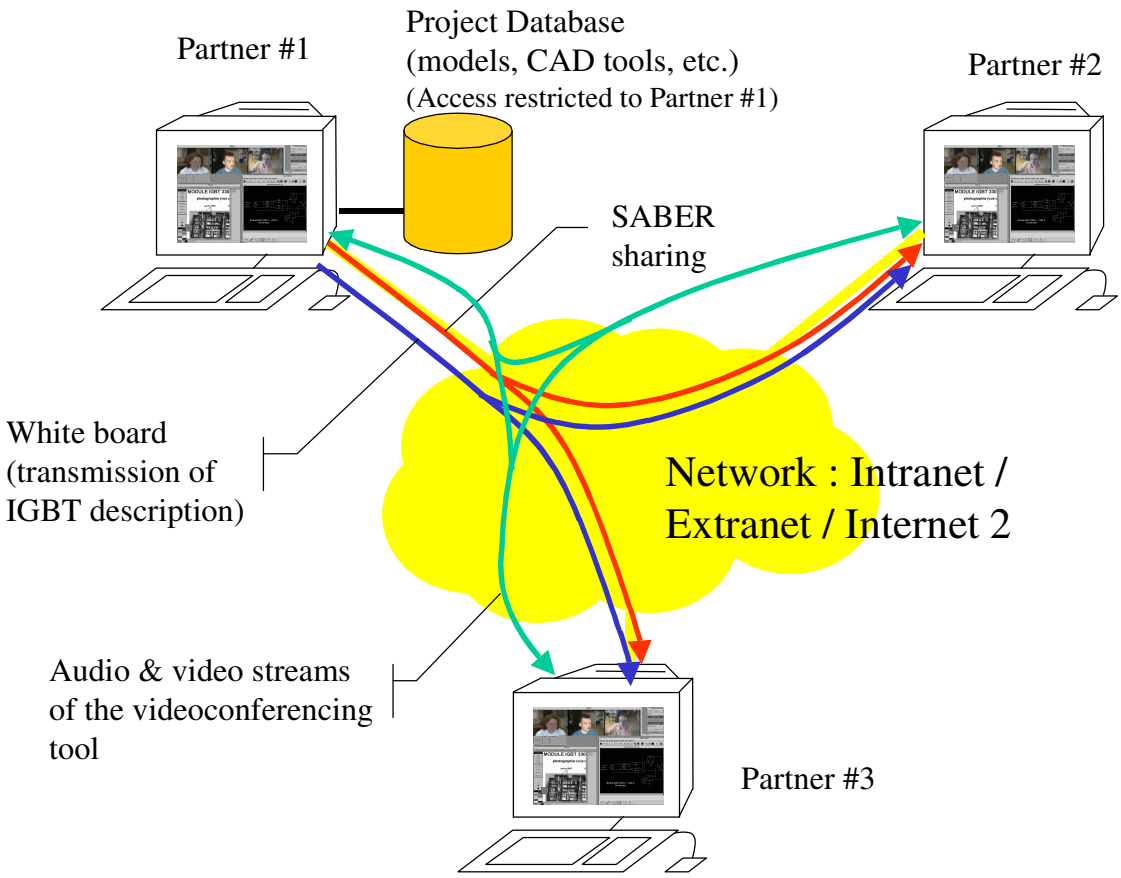


**Figure 1**. *Experiment description*

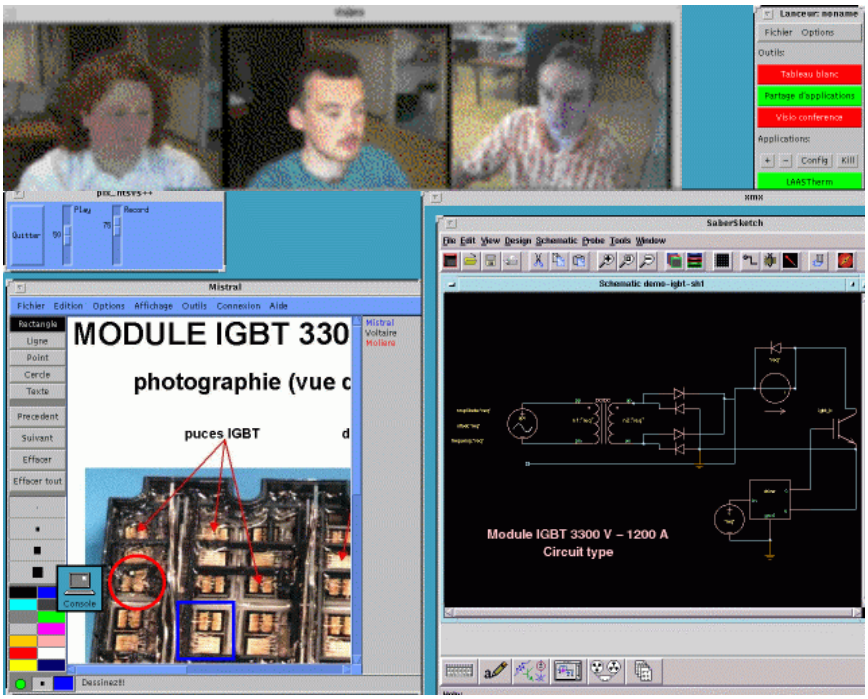


**Figure 2**. Screen copy of the experiment

## 4. RESULTS

### 1. Users point of view

After this short experiment, electronics designers have positive feeling concerning concurrent engineering because:

- Users don't have to change their way of working with the CAD and others tools they used to use;
- Number of interactions (tele-meeting) between partners are substantially improved as they are really more easier and less costly to organise;
- Concurrent engineering allows more flexibility in the way partners are working, as it is easy to organise a short meeting to solve a problem as soon as it appears, involving only the partners concerned by this problem. This flexibility is mainly due to the fact that travels are not needed: no travel costs, no time waste, etc.

And of course, confidentiality and privacy are preserved (compared to classical ways of working), as shared applications and confidential data are not transmitted on the network.

## 2. Limitations

The most evident limitation is certainly psychological as potential users are generally reserved when using synchronous cooperative working tools. It is then required to prove that concurrent engineering provides important productivity benefits in deploying easy to use and powerful tools. Nevertheless other technical limitations appear:

- Support services for distributed cooperative activities that take advantage of communication and information computing infrastructures are technically very late compared to the technological capabilities of supporting infrastructures. Thus, it exists real needs concerning generic, heterogeneous and high quality software tools for cooperative work;
- High-speed networks are currently being installed worldwide. Even if communication services are still very expensive, we can guess that their cost will not be a limitation anymore as they allow real benefits on design time cycles and travel expenses.

Nevertheless, other problems are probably going to delay the deployment of services for cooperative working as:

- Very important difficulties for **integrating** all the hardware and software components of the cooperative working environment (networks, cooperation software tools, CAD tools, etc.) that do not have been designed to work together. In addition, significant efforts have to be provided to design effective and easy to use **user interfaces** for non specialists in computer science and networks;
- **Heterogeneity** of networks, configurations of computers, and applications used by potential users. In fact, it is very difficult to find applications that are interoperable on all the computing platforms used by all the electronics designers;
- Limitations in terms of tools for group, cooperation, coordination and workflow management, as multipoints communications remain a research problem and business processes in a distributed environment have still to be defined;
- The **quality** provided by the cooperative working software tools is very changing as it can range from very good to strongly insufficient. In particular it is impossible to work if the quality of the voice received is lower than the one of classical phones. The quality has then to be ensure for the overall duration of the work session;
- The reliability and the robustness of the cooperative working tools is very poor, and globally insufficient;
- There is no help support, no monitoring information able to help users when their application stops or when the cooperative environment does not work correctly. Many previous experiments have shown that most of the time is lost in tuning the cooperation environment, or, in case of problem, in searching the crashed component to restart.

# 5. RELATED WORK

But, even if some problems remain, the search of a growing competitiveness (because of the current requirements of the market) lead many industrial enterprises to explore the domain of concurrent engineering. The use of this way of working aims at improving the quality of products, and in the same time to reduce the product life cycle and the costs (generally it aims at improving the QCD parameter: Quality / Cost / Delay).

Thus, in the European automotive domain, lead by Renault and Siemens Automotive, some experiments took place - for instance the TEAM and CANET [5] projects conduced in the framework of the European community ESPRIT projects - and showed that the concurrent engineering techniques are mature enough to be deployed. So, today, all the French Renault centres are interconnected, and some car components are designed using concurrent engineering ways. In addition, all the European automotive actors are building an automotive network (ENX: European Network eXchange) to favour relationships between all manufacturers and suppliers, thanks to synchronous (and also asynchronous) cooperative working solutions.
The aeronautical domain is also very involved in concurrent engineering in the framework of the ENHANCE project [1], that aims at deploying and install new communication infrastructures and new ways of working between the main actors of the aeronautical domain.
In the electronics domain, some experiments have also been achieved. For instance in Grenoble (France), lead by CNET France Télécom, a cooperative design platform has been created (SCADNET project). This platform relies on the C3I2 network and provides cooperation tools for SMEs of this region that then can easily cooperate. The VELA project (from Berkeley university) is an other example that relies on the use of free cooperation tools, designed in American universities, as VIC, VAT, RAT, WB [4], etc. and that have been used for remote cooperative design of electronic components. In the same way, the American GDMD project (Globally Distributed Microsystem Design) in the more specific domain of microsystems design has listed all the existing environments for cooperative work with their advantages and drawbacks.
Other experiments also exist in other domain: for instance in aeronautical tele-training (Airbus), space vehicle design (Aérospatiale Matra), etc.

## 6. CONCLUSION

As a conclusion, this experiment was really positive for electronics designers, and it should be as least as helpful for MEMS or MOEMS design and development. It represents the start point of a larger project aiming at studying, developing and then deploying concurrent engineering techniques, between LAAS and its partners. Thus this first experiment between two LAAS research groups has to be extended to interconnect external academic and industrial partners, even if some problems remain. In fact, technologies for concurrent engineering are now at the frontier between:

- Research and experimentation stages on one side and operational usage stages on actual projects on the other side,
- Stages where cooperative working is achieved thanks to asynchronous tools and stages where it includes synchronous (or real time) functionnalities,
- A time where communications services are low speed without QoS to a time where networks are high speed and provide QoS guarantee.

Most of large companies want a fast migration towards this new way of working because they are going to substantially improve their competitiveness and the QCD factor of their products. In fact, decreasing the number of travels and multiplying and improving the number of interactions and their quality makes possible to:

- Reduce travels expenses,
- Improve workers availability (because for a one hour meeting, they do not have to lose several hours travelling),
- Products can be designed faster and without errors,
- It is more easy to manage the knowledge and skills of the employees of the company,
- Improve security and information protection level,
- Etc.

But if we look wider, synchronous cooperative work can improve the social conditions of work. Thus, limiting the number and duration of travels, it should be possible to improve availability, flexibility of the employees, and it would be possible to reduce the work duration without damaging the company competitiveness. French companies that have to face a new law forcing them to limit employees work duration to 35 hours per week are then very interested by concurrent engineering to keep the same (or maybe a better) competitiveness as before the “35 hours law”.

Moreover, some technical work remains to do, for instance on new communication tools (videoconference, application sharing tools, etc.), and on the deployment of network infrastructures with new Internet technologies (known as Internet 2 or Internet next generation). Other important work has also to be performed on socio-organisational aspects of work and business process reengineering, as concurrent engineering changes some structural hierarchy in the enterprise.

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