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EDMD COLLABORATION AND VIRTUAL PROTOTYPING

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Nokia Solutions and Networks (NSN) tarvitsee tuotekehitykseensä uusia työkaluja elektroniikka- ja mekaniikkasuunnittelun yhdistämiseen. Tutkimuksen ensimmäisessä osassa esitellään Electrical Data Mechanical Data (EDMD) sovellus, suoritetaan testaus projektilla ja selvitetään työkalun mahdollisuudet ja haasteet NSN:n käyttöympäristöä ajatellen. Tutkimuksen tuloksena kerättyä tietoa hyödynnetään jatkotoimenpiteistä päätettäessä muun muassa työkalun laajemman käyttöönoton osalta. Toinen osa tutkimuksesta käsittelee virtuaalista prototyyppien kehittämistä toimintatapana ja siinä käytettäviä simulointityökaluja. Ensimmäisessä osassa tutkittu EDMD -työkalu on yksi osa simulointiympäristöä. Tavoitteena on testata virtuaalista prototyyppien tekemistä oikeassa tuotekehitysprojektissa ja saada siitä käyttökokemusta NSN:n toimintatapojen kehittämiseksi.

EDMD -työkalun testaus ja sopivuus NSN:n ympäristöön suoritettiin lyhyen mutta intensiivisen testijakson aikana. Testaus suoritettiin NSN:n ympäristössä ennalta mietittyjen testaussuunnitelmien mukaan viiden asiantuntijan ryhmässä. Virtuaalinen prototyyppien kehittäminen suoritettiin oikealla projektilla; projektiin osallistuvat työntekijät ohjeistettiin uuteen toimintamalliin ja simulointityökaluilla kerätty testausdata analysoitiin asiantuntijoiden kanssa.

EDMD -työkalun testaus onnistui hyvin tiukasta aikataulusta huolimatta. Hyvän työkalutuen avulla suurin osa ongelmista ratkaistiin nopeasti ja kaikki testaussuunnitelman kohdat ehdittiin käydä läpi. EDMD -työkalussa on selkeästi potentiaalia, sillä visuaalisen avun lisäksi se mahdollistaa paremman kommunikoinnin eri suunnittelualueiden välillä. Myös koeponnistettu toimintatapa virtuaalisesta prototyypin kehityksestä sai positiivista palautetta projektiryhmältä.
Tutkimuksen tuloksena laadittiin raportti NSN:lle jatkosuunnitelmien toteuttamista varten.

Asiasanat: EDMD, virtuaalinen prototyyppien kehitys, simulointi

ABSTRACT

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Nokia Solutions and Networks (NSN) requires new tools for collaborating electronic and mechanic design phases in its product development. In the first part of this thesis will be introduced Electrical Data Mechanical Data (EDMD) application; the software will be tested within a project to resolve tool's possibilities and challenges from NSN's point of view. Results of the study will be used for deciding further usage of the tool. Secondly the thesis will study virtual prototyping as a new working method and also related simulation tools. Tested EDMD tool is one module of the simulation environment. Virtual prototyping will be tested within real product development process and experiences of team members will be utilized to improve NSN's practices.

EDMD tool's suitability for NSN's development was tested during short but intensive testing period. Tests were carried out by five experts according to predecided testing plan. Virtual prototyping was trialed in project of which team members were instructed to use the new way of working. Simulation tools were tested in same project and collected testing data was analyzed with experts.

Testing of EDMD tool succeeded despite of the tide schedule. Tool support was excellent and majority of problems was solved swiftly enabling performance of all planned testing tasks. EDMD tool clearly has potentiality as in addition of visual aid it improves communication between separate design modules. Also new practice of using virtual prototyping received positive feedback from the project team. As a result of the study a conclusive report was presented to NSN for further actions.

Keywords: EDMD, Virtual Prototyping, Simulation

CONTENTS

TIIVISTELMÄ 3

ABSTRACT 4

TERMS AND ABBREVIATIONS 6

1 INTRODUCTION 8

2 EDMD COLLABORATION 9

2.1 Problem statement 9

2.2 ECAD 10

2.3 MCAD 12

2.4 Constraints 13

2.5 History of EDMD 14

2.6 CAD implementation 16

2.7 Current design flow 20

2.8 Current solution 21

2.8.1 IDF 22

2.8.2 DXF 23

2.9 Advantages of EDMD integration 25

2.10 Implementation 26

2.10.1 Operating 27

2.10.2 Challenges 30

2.11 The way forward 31

2.12 Results and conclusion 32

3 VIRTUAL PROTOTYPING 34

3.1 Problem statement 34

3.2 Background 34

3.3 Current design flow 36

3.4 Existing solutions 36

3.5 Virtual prototyping modules 43

3.6 Data management 49

3.7 The way forward 52

4 CONCLUSION 54

REFERENCES 56

APPENDIX 59

TERMS AND ABBREVIATIONS

CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CAM	Computer-Aided Manufacturing
DFM	Design for Manufacturing
DWG	Drawing
DXF	Drawing eXchange Format
ECAD	Electronic Computer-Aided Design
EDA	Electronic Design Automation
EDMD	Electrical Data Mechanical Data
EMC	Electromagnetic Compatibility
IDF	Intermediate Data Format
IDX	Incremental Data eXchange
MCAD	Mechanical Computer-Aided Design
MCAM	Mechanical Computer-Aided Manufacturing
NPI	New Project Introduction
NSN	Nokia Solution and Networks
OS	Operating System
PCB	Printed Circuit Board
PDM	Product Data Management
PI	Power Integrity

PLM	Product Lifecycle Management
PWA	Printed Wiring Assembly
PWB	Printed Wired Board
PTC	Parametric Technology Corporation
R&D	Research and Development
SI	Signal Integrity
STEP	Standard for the Exchange of Product model data

1 INTRODUCTION

NSN is looking for means to improve the company's internal product development processes. Obviously, in an international company of NSN's size, fluent project performance also has a remarkable effect on the cost level. Currently the development process consists of several, individual design phases and most of the prototyping tests are carried out with physical parts. The starting point for this master thesis was NSN's need to have more flowing processes through improved communication and prototype simulation.

In a product development process the designing of mechanic and electronic parts has a major role. Interactive communication between the design phases is not possible with current tooling and therefore NSN is considering implementing the so called EDMD tool. A prior version of EDMD tool was tested at NSN few years back but at that time the software was inadequate for NSN's use. The scope of this study is to define whether the current version of the EDMD tool would be suitable for NSN. There are other software for same purpose but NSN has restricted options specifically to the EDMD tool by same the suppliers which are delivering the design software in use. The actual tool testing will be carried out in a simulated project to discover possible disadvantages and to find out if the tool really facilitates communication between mechanic and electronic designs.

Prototype simulation is a part of every product development project. NSN has invested remarkably to simulation tools but currently the simulation results are overshadowed by tests with physical prototypes. Considering the duration of the projects NSN would have clear benefits of using virtual prototyping and therefore testing the new approach was set as another scope of this study. Virtual prototyping will be tested within an actual product development project to evidence that the practice would apply to NSN's design process. Efficient virtual prototyping requires well-organized data management which also has an important role from communication's point of view. The thesis presents alternative solutions for the company's data management.

2 EDMD COLLABORATION

2.1 Problem statement

> In today's global market, the pressure to create smaller, more intelligent products in less time is forcing design engineers to critically reassess and revise the overall product design process – from concept right through to manufacture.
> The need for change is further fueled by the rapid development of electronics technology, which in a series of evolutionary steps has altered the fundamental processes we use to create today's electronic products. The emerging challenge for product development teams is managing and working with these increasingly interdependent processes while meeting production deadlines.
> As electronic products and the processes used to create them evolve, the fundamentally dissimilar worlds of electronic and mechanical design need to work in harmony. To stay competitive in today's market, designers must adopt systems that unify the design process and allow the smooth flow of design data across the electromechanical divide (1.)
>
> Currently available methods based on data exchange formats do not permit collaboration. The IDF format, for example, is not suitable for adequate collaboration due in particular to its limitations when changing the position of components, inadequate functionality when defining data ownerships and the lack of an option for performing incremental data exchange. There are also no data management functions for implementing satisfactory change and versioning processes. The handling of constraints as well as their exchange and administration also remains an unresolved task within the framework of ECAD/MCAD collaboration (2, p10.)

Nowadays most companies try to improve their competitiveness by savings in operation flow, with tighter schedules and strict quality control. It is not easy to combine these targets and in fact, separate improvement actions can be totally conflicting. When project schedules are tightened and project time is shorter, the tools in use must be exploited for possible time saving. Nevertheless, even with tightest timelines the quality must not be affected. Several new tools streamline designing process and enables simultaneous design works to be performed at different locations. Implementation and introduction of new tools requires some time and practicing, but in many cases it pays off. Still it is quite common that old practices are considered so well that the properties of the tools are not even studied through. For example, combining mechanics and electrical circuit board design can be slow and complex due to multiple files in use. Also this phase of the process is very vulnerable for human mistakes; the used file might be an old version, some mechanic part may be missing or the electronic design is lacking some parts. Monitoring Mechanical Computer-Aided Design (MCAD) and Electrical Computer-Aided Design (ECAD) sections within finalizing phase is vital but very challenging without collaboration tool.

Many software manufacturers have been developing products to solve those common problems described and the result is an EDMD collaboration tool. In the development of electro-mechanical products, the ideal process of concurrent engineering would be parallel work of electronic and mechanic engineers that are aware of simultaneous work of their colleagues and they can collaborate when necessary. However, this concept of concurrent engineering in electro-mechanical product development cannot be realized unless a direct communication between MCAD and ECAD systems exists. Hence, overcoming this barrier of systems integration would release a tremendous efficiency potential with regard to the development of electro-mechanical product since the product's time-to-market would be significantly reduced and thereby increasing the company's productivity.

2.2 ECAD

"ECAD is fundamentally a two-dimensional layout tool" (3, p8).

> Computer-aided engineering tools cover all aspects of engineering design from drawing to analysis to manufacturing. Computer-aided design (CAD) is a category of CAE related to the physical layout and drawing development of a system design, CAD programs specific to the electronics industry are known as electrical CAD (ECAD) or electronic design automation (EDA). EDA tools reduce development time and cost because they allow design to be simulated and analyzed prior to purchasing and manufacturing hardware. Once a design has been proven through drawings, simulations, and analysis, the system can be manufactured (4, p1.)

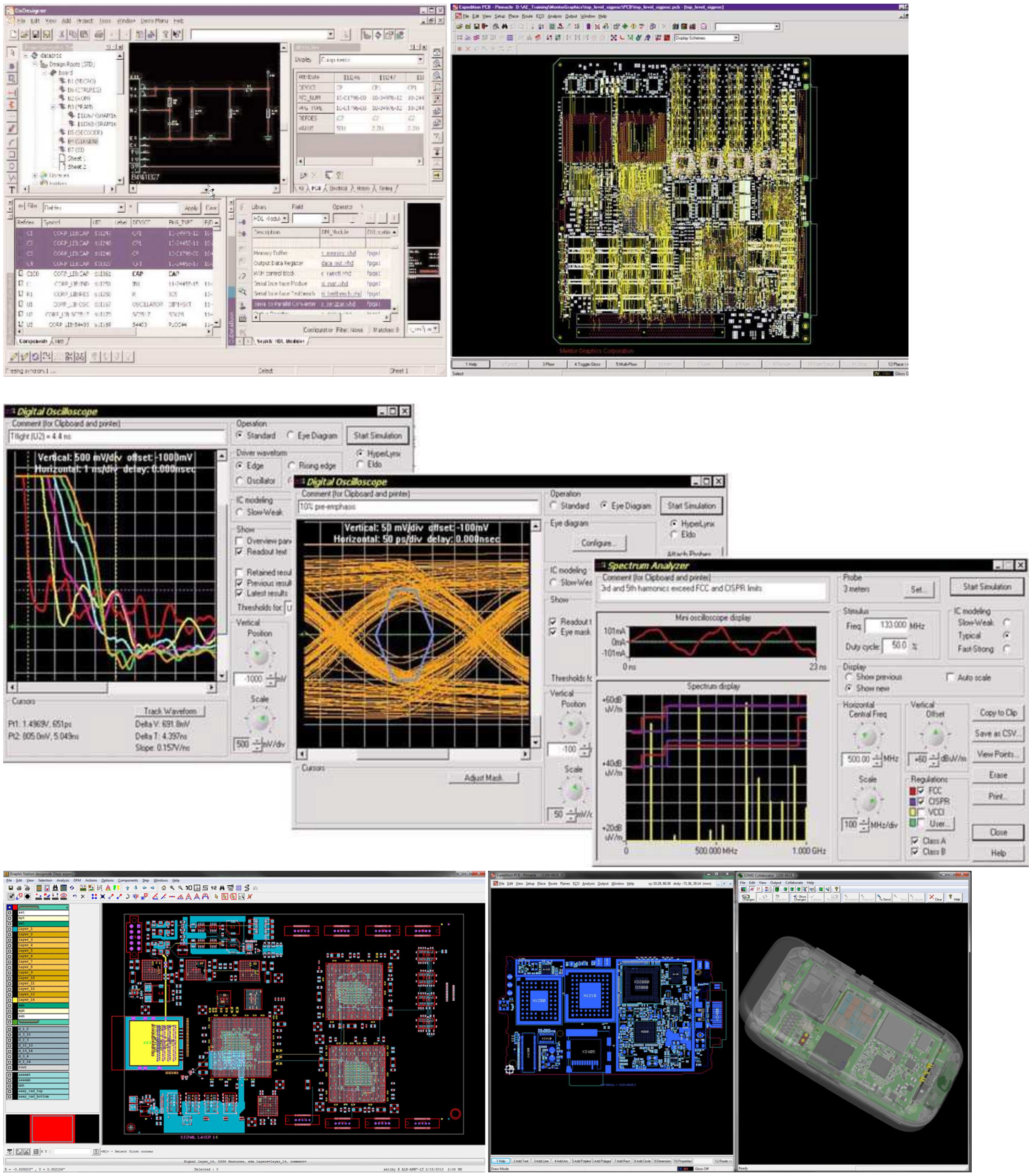

FIGURE1. ECAD tools by Mentor Graphics: DxDesigner, ExpeditionPCB, Hyperlynx, ValorNPI and EDMD Collaboration tools (5, p.2, 3, 8)

Figure 1 presents typical Mentor Graphics ECAD tools such as a design creation tool DxDesigner schematic, a simulation tool Hyperlynx, a Printed Wired Board (PWB) layout (place and routing tool) Expedition, a variety of collaboration tools (EDMD, CES, VisECAD, XtremePCB), a Library Management System

(LMS), as well as Design for Manufacturing (DFM) and New Project Introduction (NPI) tools. Other software manufacturers have similar selection of tools. A design with ECAD is usually performed with various tools and is combining work of many designers. The current version of ECAD enables parallel working of designer which makes process faster.

2.3 MCAD

Mechanical computer-aided design (MCAD) and mechanical computer-aided manufacturing (MCAM) are enormously sophisticated disciplines, capable, for example, of designing an airplane of several million assembled parts. The major software systems for mechanical design (MCAD) are parametric, solid-modeling, feature-based systems. These terms are explained as follows:

Parametric. This means that the physical shape of an object is determined by a number of constraints – e.g., a hole appears at the center of a block, or at a specific distance from one edge. If you modify the object, e.g., change the size of the block, the constraints will propagate with the changes, e.g, the hole will appear at the center of the modified block, or at the same specific distance from one of its edges.

Solid modeling. This refers to the fact that what is constructed is not a surface model, but a model with material between the surface. This is useful for many aspects of MCAD, for example, because the eventual machining of the object will be achieved by the removal of material, e.g., by drilling or milling.

Feature-based. This means that the object is designed by adding successive features. Standardly, MCAD programs such as Pro/Engineer and Mechanical Desktop use three types of features: (a)Sketched features. These begin with sketching a profile curve on a 2D plane. The sketch is then resolved (i.e., cleaned); and finally it is swept to create a 3D object.

(b) Placed features. These are standard features such as holes, cuts, pockets, chamfers, rounds, slots, and shafts. They are pre-existing in the software, and therefore the user merely has to instance and place them at run-time. Therefore, the use of these features avoids sketching.

(c) Datum features. Conventionally these are understood not as physical parts of the object, but are used as reference elements in the process of designing the object; e.g., as reference points, axes, and planes (6, p299.)

Usually the mechanic design is performed with a single software, handling each design object separately. In general the mechanic design contains several parts within same project and the designer needs to notice demands of different sections. In addition of actual designing the work includes data management and information sharing to other designers. Figure 2 presents a typical MCAD design view.

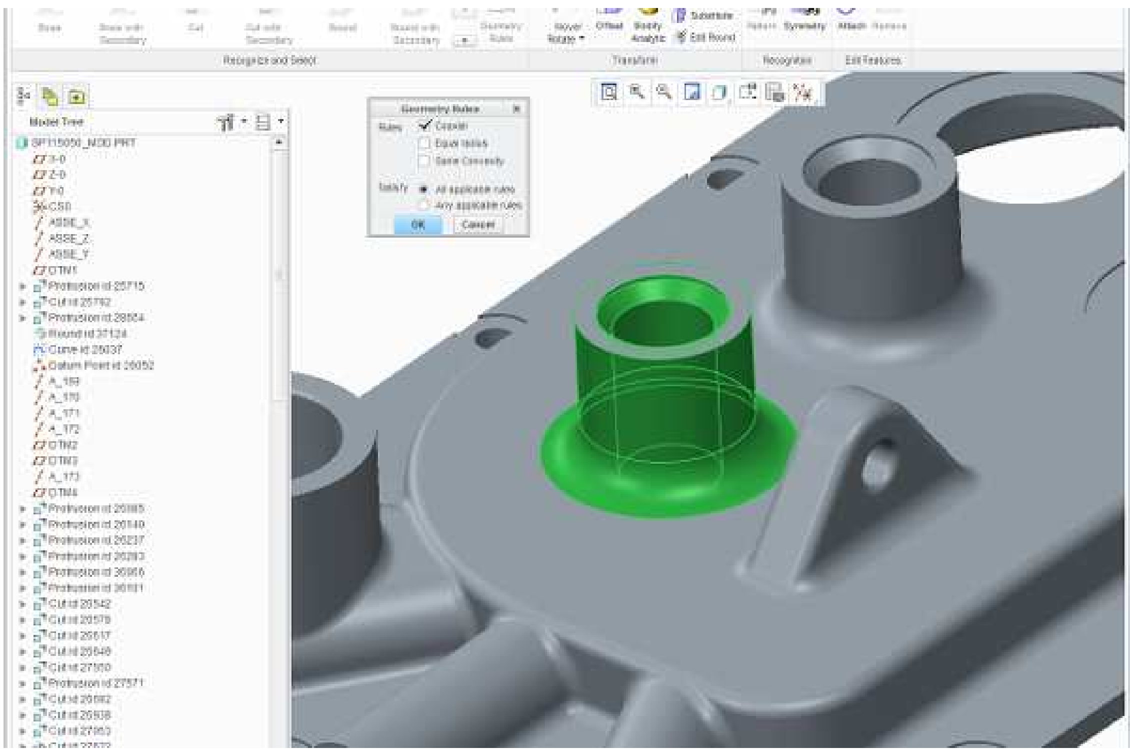

FIGURE 2, MCAD tool, Creo 2 by PTC (7)

2.4 Constraints

The original plan was to use a new release of MCAD tool for testing purposes to study in practice the EDMD collaboration tool. The release of new version was, however, postponed so the testing has been carried out with the current version. Most of the planned tests were possible to be performed; only few interesting features remain to be tested in future.

The testing results would have been more comprehensive if it would have been possible to test more than just one collaboration tool. This was not possible within the timeframe and also new collaboration tools may be incompatibly with the current design tooling in use. Mentor Graphics' collaboration tool is being used in the testing environment and hence it was easy to have support for testing the new tool.

Testing the new tool involved altogether four design specialists who were required to use the collaboration tool in their daily work for different kind of design tasks. Some challenge was encountered to arrange enough time to test persons to perform the test, as many of the specialists were busy with their own ongoing projects and testing the collaboration tool was an additional task for them.

2.5 History of EDMD

> For nearly 20 years, the Intermediate Data Format (IDF) has been the preferred file format for exchanging basic design information between the ECAD and MCAD systems that PCB layout designers and mechanical designers use to design electromechanical products." "IDX grew out of discussions between Mentor Graphics and Parametric Technology Corp. and their customers about ways to enable more collaborative use of their respective tools on designing electromechanical products. Faced with the challenges of designing smaller, more complex products, the customers were asking for a design collaboration solution that could not be developed around the IDF.
>
> As a result of these discussions, they engaged the ProSTEP iViP Association, a standards development consortium based in Germany, to develop a new data exchange format for ECAD/MCAD design collaboration and make it available to the entire CAD vendor and OEM community. A project group was established, and work on the new format began in 2006.
>
> The project group created a data model for ECAD/MCAD collaboration called the EDMD (Electronic Data Mechanical Data). The EDMD data model borrows from STEP (Standard for the Exchange of Product model data), an international standard, specifically, Application Protocol (AP) 214 "Core Data Model for Automotive Mechanical Design Processes" and AP 210 "Electronic Assembly, Interconnection, and Packaging Design." In addition, a goal of the project group was to incorporate the concepts and content of IDF 3.0 in the initial data model (8.)

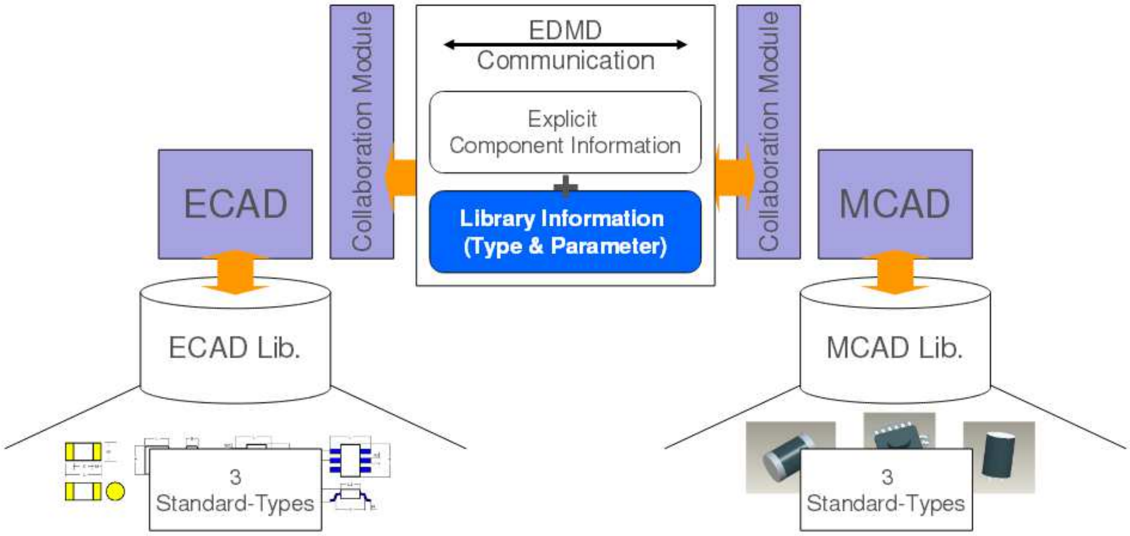

FIGURE 3 EDMD collaboration flow (9)

Figure 3 presents well the interaction between MCAD and ECAD; both the ECAD and MCAD software contains a design tool, a component library and a collaboration tool. The communication between the design software passes through the EDMD tools with a data transfer based on Incremental Data eXchange (IDX) format.

As noted in the story above the EDMD collaboration has been demanded over longer period of time. Currently a lack of collaboration tool leads to poor and inflexible communication between separate sections in the design, resulting to loss of both money and time. Moreover, this also affects the quality in negative way. The EDMD collaboration streamlines the design process as a whole and significantly reduces the possibility of errors.

> Every PCB design is at least in part driven by the mechanical aspects of the product for which it is being designed. The shape of the board outline, locations of mounting holes, connectors, switches, and so on, are constrained by the system or enclosure in which the PCB will be mounted. The ECAD (Electronic Computer Aided Design) and MCAD (Mechanical Computer Aided Design) groups might be working on the same product, but creating PCB and mechanical designs independently from each other. These ECAD and MCAD groups could be co-located, separated by several time zones, and might not even be part of the same company. Over the

> product development period, it is very likely that either organization might need to make changes to their design that could impact their counterpart organization. Prompt understanding, communication, and agreement of such changes becomes important in managing development costs, and to the overall success of the product. Today, communication methods used to explain and adopt such changes are often limited to emails, phone conversations, and marked up drawings. These methods are sometimes inefficient and can lead to mis-communication and confusion, resulting costly errors later in the manufacturing process. To solve these problems, the Mentor Graphics ECAD-MCAD Collaborator provides an application and user interface that engineers in both organizations can use to capture and collaborate on minor iterations and changes in the design that could potentially affect design parameters in the other organization (10.)

The EDMD collaboration tool development originated from an insufficient communication between MCAD and ECAD; this was also a start for an IDX standard which has now proceeded to version 2.0.

2.6 CAD implementation

The incremental Data eXchange (IDX) format is developed and created by PTC and Mentor Graphics, but also many other manufacturers have chosen to integrate it to a part of their own products. Several manufacturers have started actions to develop their own EDMD collaboration tool, with their own approach. The following presents the situation and the existing solutions of few well-known manufacturers.

> Cadence. Support for IDX is built directly into Allegro 16.5 as a standard feature. Versions 1.2 and 2.0 of IDX are both supported. Importing and exporting IDX files in Allegro is similar to importing and exporting IDF files, including the ability to configure export filter settings. Importing an IDX change file brings up a form that lists all the proposed changes. Selecting an item from the list previews the change in the design so you can see the effect of the change before accepting it. Similarly, when exporting changes, a form is displayed showing all the changes made since the last synchronized state of the design. You can choose which items to include in the IDX change file from this form. As with the IDF, Allegro also provides a batch executable command for exporting IDX files from the Allegro command line or from an OS command prompt. A batch command for importing IDX files is not provided because importing requires users to preview, accept, and reject changes.

Dassault Systèmes (Catia). Dassault Systèmes is working to implement IDX for its CATIA Circuit Board Design and CATIA Flexible Board Design products. The IDX interface will be implemented by a DS Development Partner, CadCam Design Centar D.O.O.
CATIA currently manages PCB exchanges through IDF 2.0 and 3.0 in CATIA Circuit Board Design and CATIA Flexible Board Design. With CATIA V6, collaboration and synchronization between electrical and mechanical PCB designs is ensured by IDF file sharing. To improve this sharing, IDF files are saved directly within the V6 Platform, ensuring full synchronization at all times, and efficient traceability of design changes.

Dassault Systèmes (SolidWorks). Solidworks support for IDX is provided by the CircuitWorks add-in included with SolidWorks Premium 2012. The CircuitWorks add-in supports both IDX versions 1.2 and 2.0, as well as Mentor PADS .asc files and all versions of the IDF.
CircuitWorks sets up a common folder for exchanging IDX files with ECAD and constantly monitors this folder, sending notifications whenever a new IDX file comes in. If a common folder cannot be set up, CircuitWorks can be configured to automatically email IDX baseline and change files.
Once a baseline is established and an IDX change file is imported, proposed changes can be viewed and accepted or rejected. A one-button operation updates the SolidWorks design with the accepted changes and exports an IDX change file for synchronizing with ECAD. CircuitWorks maintains a model tree showing the history and status of all changes.

Mentor Graphics. Mentor's ECAD-MCAD Collaborator (EDMD) supports IDX versions 1.2 and 2.0 for the Expedition Enterprise, BoardStation XE and PADS design flows. The ECAD-MCAD Collaborator provides a 3D visualization environment to review, accept, and reject IDX change proposals from MCAD. Detailed 3D models of electronic and mechanical parts can be imported to help evaluate the effects of the proposed changes. Mechanical packaging data can also be imported so that a complete product assembly with multiple PCB databases can be built completely within the PCB environment.
The ECAD-MCAD Collaborator also allows dynamic view following with the PCB tool. If a part is moved in the PCB tool, the 3D view updates in real time. Panning, zooming and layer display changes in the PCB tools also dynamically update in the Collaborator.

PTC. Creo, PTC's suite of design software, and Pro/Engineer Wildfire both support IDX.
IDX support for Creo Parametric, PTC's 3D parametric design app, is provided with the ECAD-MCAD Collaboration Extension (ECX), available beginning with Pro/Engineer Wildfire 5.0. ECX supports both versions 1.2 and 2.0 of IDX.

With ECX, IDX baseline files can be exported or changes proposed for exporting in an IDX change file. One could either manually select the changes to propose from the Creo Parametric assembly or use the compare functionality to propose all changes made since a previous saved version of the board assembly.
When importing IDX files, Creo View ECAD Validate lets you select the proposed changes from a transaction list and preview them in the Creo Parametric assembly. Once it's been decided which changes to accept or reject in the transaction list, they can be approved to update the assembly and then saved in a new IDX file for ECAD to synchronize the design accordingly.
Creo View ECAD, PTC's standalone visualization app for ECAD, also supports importing both versions 1.2 and 2.0 of IDX for graphical visualization.

Siemens PLM. NX 8 provides support for IDX through a fully-embedded application called NX PCB Exchange. NX PCB Exchange is developed by Maya Heat Transfer Technologies, an OEM technology partner with Siemens PLM Software.
NX PCB Exchange currently supports baseline IDX version 1.2 transfers. However, NX PCB Exchange also has the ability to compare, preview, and accept/reject changes in IDF files. This functionality will be extended in the near future to support incremental IDX changes. IDX 2.0 files will also be supported.

Zuken. Zuken supports IDX for CR-5000 with the Zuken Interchanger for Creo. As the name suggests, the Zuken Interchanger for Creo is currently optimized for use with Creo Parametric and was developed cooperatively with PTC. Over time, as CAD industry support for IDX matures, Zuken expects to use it with other MCAD systems as well.
The Zuken Interchanger for Creo supports IDX version 2.0 and can exchange both baseline and change files. It also provides filtering capabilities when exporting from CR-5000 so that designers can limit the number and type of design objects included in the resultant mechanical model (11.)

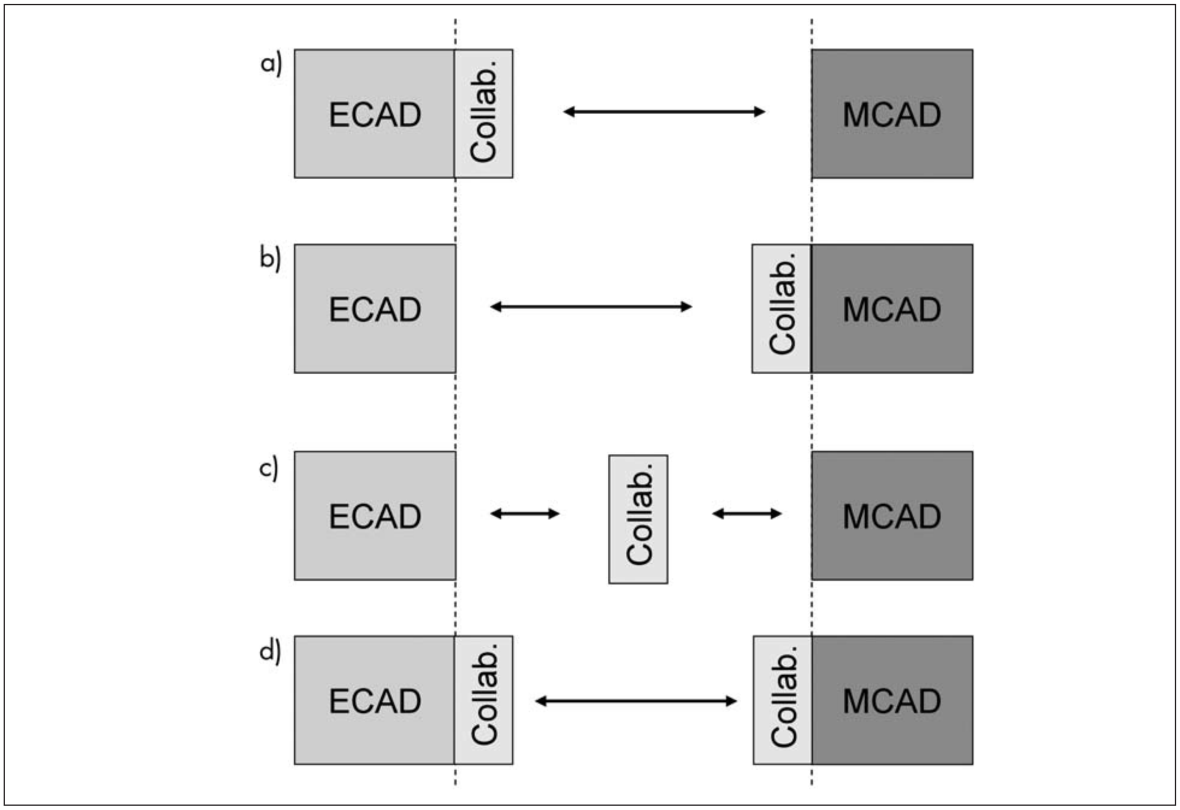

FIGURE 4 Communication platforms

There are a number of different ways in which the communication platform between ECAD and MCAD can be implemented (cp. figure 4):

a) Integration of the collaboration module in the ECAD system, in which case communication takes place directly with the MCAD system.

b) Integration of the collaboration module in the MCAD system, in which case communication takes place directly with the ECAD system.

c) Separate collaboration module which controls only the collaboration and which is provided with the respective data from the authoring tools.

d) Integration of a collaboration module in both the ECAD and the MCAD system. Communication then takes place between the two collaboration modules (2, p13.)

The IDX standard could be used in any model presented in the figure 4; for the testing project NSN has chosen the tools according to the model d). Both design tools have separate EDMD modules which are connected for data transfer.

2.7 Current design flow

The current design flow, presented in figure 5, consists of only data transfers in Drawing eXchange Format (DXF) or IDF format in the beginning and in the end of project. A possibility of human errors increases due to the restricted communications. The data files contain whole design data and the size of files grows remarkably which in turn complicates modification and controlling of the data.

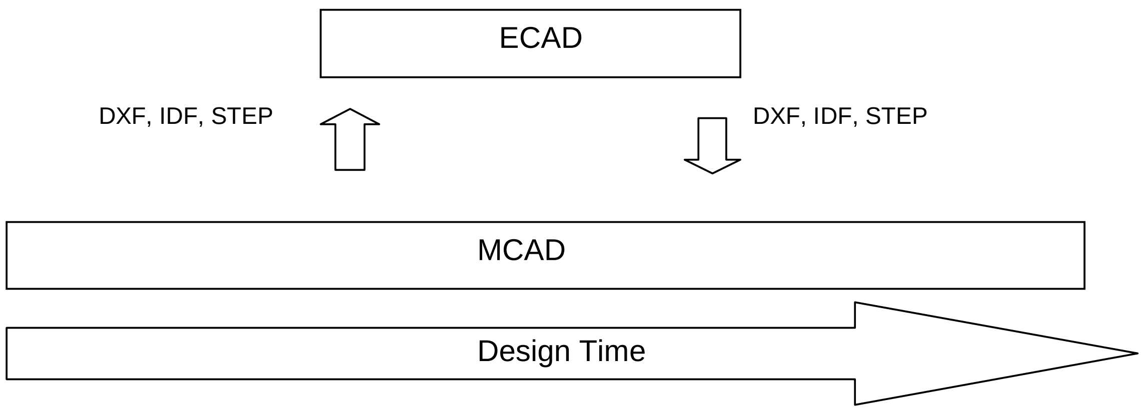

FIGURE 5 Current design flow

1. MCAD defines: Board outline, cutouts, keepouts, mounting holes and fixed components

- In general, the mechanics of a dominant party specifies the size of the circuit board. Similarly, the circuit board connectors are typically set on the mechanics. Mechanics can also define the height of the components that may set restrictions for areas where components, vias or wiring cannot be placed.

2. MCAD converts DXF or IDF file and sends it to ECAD

- Depending on the case and the type of data to be transferred to ECAD, either IDF or DXF format is being used. Using DXF is recommended if designer wants to shape up the layout of the background. IDF is a practical tool to update board edges and defining keepouts.

3. ECAD imports DXF or IDF file and defines the design structure

- The layout designer ensures that the data transfer was successful from mechanics and all the necessary information can be found in DXF or IDF file.

4. ECAD converts IDF or Standard for the Exchange of Product model data (STEP) file and sends it to MCAD

- The layout designer will export DXF or IDF file to the mechanic designer depending on which format is more practical. The IDF is often used as it easily demonstrates components' height information on mechanic tool. The problem lays in relocation of vias and wiring which has to be carried out manually.

5. MCAD verifies components' height and location etc

- The mechanic designer imports the file to the mechanic tool and simultaneously inspects the design of components, connectors and the board in general so that all parts are located correctly. Also a possible collision must be verified if the file contains vias or wiring.

6. Loop continues as long as the design is ready for manufacturing

- If errors are detected it might be necessary to resend the files number of times and make further amendments. All the checking are performed visually, which is rather slow and the possible mistakes are difficult to notice.

2.8 Current solution

One of the main problems is a slow information flow and the repeated need to convert new files. Since the IDF and the DXF files are slow and laborious to convert, the files are not made in time and this is due to the poor communication between the mechanics and the layout. In general, the data is being transferred to the layout before starting to work and in the end at the final stage of layout. This kind of data transfer can result to time-consuming changes during the final stage in both MCAD and ECAD. In final phase the time to find errors is very limited and possible only either MCAD or ECAD can react to the change. The IDF and the DXF are illustrative but those can only be checked visually by users and the amendments are difficult or nearly impossible to self-check.

DXF's benefit is that it is widely supported by most of the design programs which can export DXF file for example to simulation tools. The DXF can be saved as a component in the layout and designer can easily move it if necessary. Also the IDF is supported by many mechanics and layout tools. The IDF allows easily to determine high components' compatibility with mechanics and to limit keepouts.

2.8.1 IDF

> Intermediate Data Format (IDF) for exchanging data between electrical and mechanical CAD/CAE systems for use in 3D design and analysis of printed wiring assemblies (PWAs), thus allowing users of these systems to participate concurrently in the design of electro-mechanical products. In a typical electro-mechanical design process for example, a mechanical CAE system may require a solid model of a PWA for form fit analysis in designing the enclosure for the final product. The electrical CAE system, on the other hand, requires 2D board outline and critical component placement information to layout and route the PWA design (12.)

The IDF file transfer system is an effective way to transfer information from ECAD package to MCAD package. The IDF file is ASCII file format that contains ECAD information depending on the IDF version (2.0, 3.0 or 4.0), such as component name, component location, component outline geometry definition; board outlines even mounting holes panel and 3D shapes. (See appendix 1). Figure 6 presents a typical view of ECAD design in MCAD view.

As a major disadvantage, the 4.0 version is not fully supported yet (as input/output data) by the majority ECAD tools including Mentor Graphics Expedition, Zuken or Allegro. The ECAD-sized manufacturers have changed or are in process to change to the next IDF's version, IDX (EDMD) collaboration tool, that is widely supported by a number of manufacturers.

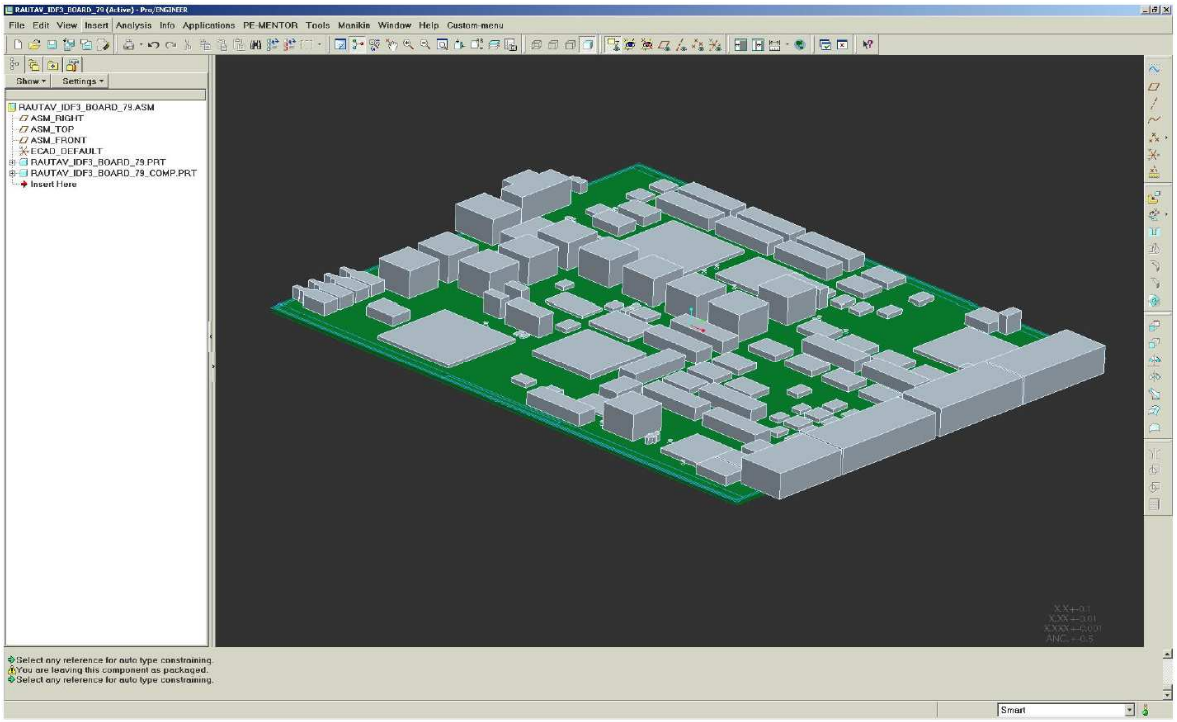

FIGURE 6 ECAD design imported to MCAD

2.8.2 DXF

DXF (Drawing eXchange Format) is the Autodesk-approved format for exchanging drawing data between different CAD programs. (Some other vector graphics applications, such as drawing and illustration programs, read and write DXF files, too.) DXF is a documented version of the undocumented DWG format. Because DXF more-or-less exactly mimics the DWG file's contents, it's (usually) a faithful representation of AutoCAD drawings.

How well DXF works for exchanging data depends largely on the other program that you're exchanging with. Some CAD and vector graphics programs do a good job of reading and writing DXF files, while others don't. In practice, geometry usually comes through well, but properties, formatting, and other nongeometrical information can be tricky. Test before you commit to a largescale exchange, and always check the results (13, p392.)

It has been updated several times, and the latest version (Release 14) supports both ASCII and binary forms. Files created with the earlier versions can also be opened with the later releases.

> A DXF file is composed of several sections - in the following order: Header (contains general information about the drawing); Classes (contains application-defined information); Tables (contains item definitions); Blocks (contains descriptions of entities); Entities (contains drawing entities); Objects (contains data of non-graphical objects); and Thumb-Nail-Image (contains preview of image). Each section has a code that is associated with its value. The code begins with a 0 followed by a string, and ends with a 0 followed by ENDSEC (14.)

A major benefit of the DXF format is that it is widely supported by numerous software. Despite the same format, in some cases the data files need to be modified before importing and this creates possibilities for mistakes. The DXF format is rather light to handle so it is worth of considering for the data transfer between MCAD and ECAD. Figure 7 presents a typical MCAD design imported as DXF file to ECAD.

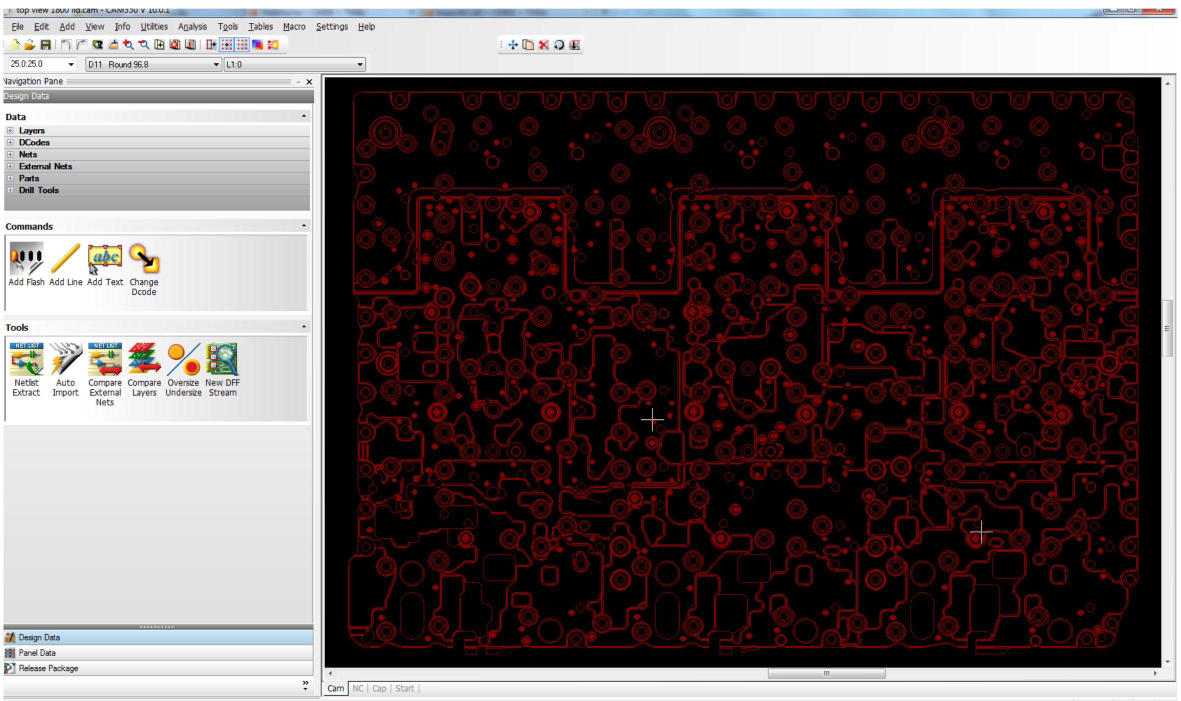

FIGURE 7 DXF file imported from MCAD to ECAD

2.9 Advantages of EDMD integration

> As John MacKrell, senior CIMdata consultant, says: "The bottom line is that the benefits of implementing an ECAD-MCAD collaboration strategy today can bring both positive and broad-reaching benefits that can be not only financial, but improve product design quality (15.)
>
> The integration of mechanical and electrical components in mechatronic integrated products is becoming increasingly important. Development takes place in separate domains using different CAD tools (ECAD and MCAD). Although powerful software tools are available on the market for the respective disciplines, support for existing processes and systems is reaching its functional limits with regard to collaboration between these systems. With increasing product complexity and the demand for shorter development cycles, there is a growing need for feasible solutions for sustainable collaboration on the basis the existing ECAD and MCAD systems (2, p2.)

The benefits of the EDMD collaboration are faster engineering change resolution, more functionally valid designs and increased product design innovation. The IDX is a file type trying to tackle the problems and to improve weaknesses within the DXF and the IDF formats. The data does not need to be manually transferred nor does it require to be edited manually. MCAD and ECAD follow the design progress of other section and are able to react on possible errors already in early stage. There are some compatibility problems within the different tools even though the DXF is widely used and supported format. For example, the DXF file needs to be manually edited in another Computer-Aided Manufacturing (CAM) tool before layout importing, as there are lots of unnecessary text, layers and shapes. Along the EDMD collaboration it is possible to gain traceability and to have the co-operation on a whole new level. With the collaboration tool the design changes can be accepted or rejected and update of this information is available immediately to other designers. The real time information flow reduces the risk of errors and this in turn may lead to innovative solutions in the design cycle.

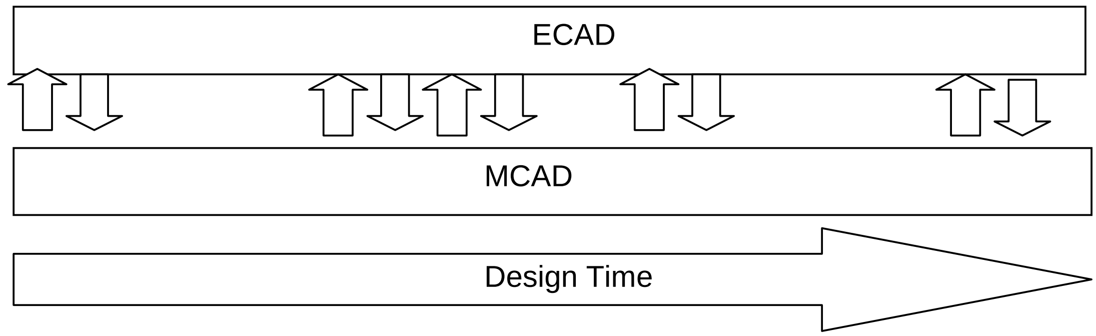

FIGURE 8 EDMD design flow

The figure 8 presents how active the exchange of information is throughout the whole planning and design process; with the aid of collaboration tool the design work of electronics and mechanics can begin at the same time and continue within the framework of the project as long as needed.

2.10 Implementation

The starting point of this study was NSN's need to define the usability of existing EDMD collaboration tool in its own development environment. As a part of the research, an internal report will be prepared for NSN regarding suitability of the studied collaboration tools with proposal whether the tool should be explored further.

Several years ago NSN had a project regarding collaboration tools. At that time the tools were not on such technological level that required by NSN so the project was left on hold. Since then the tools have been improved remarkably and hence it is time to re-evaluate the tools. The collaboration tools to be studied were Mentor Graphics' EDMD layout tool and PTC's Creo 2 EDMD tool. In addition a tool for ECAD part by PTC will be studied if possible within the timeframe of the study.

Tooling for both the mechanics and the layout design has been updated to new versions and hence the timing of the study is excellent. The implementation of both tools is still in starting phase so it is practical to add the implementation of collaboration in same project.

2.10.1 Operating

The evaluation in practice was started by defining the tasks and the timetable for performing the needed tests. The tasks were shared to the members of the project team which consisted of four experts of NSN's tool development. The project team was deliberately kept small so that an intensive progress would be possible along members' normal work load.

The overall time period for the whole project was planned to be three months. The schedule is rather tight considering that also the final project report and possible decisions of further actions should be completed in the same time frame. However, the short project duration ensures more efficient working pace and moreover, the decision of future utilization of the evaluated tools is expected in short term by NSN.

The testing objects were defined strictly based on the NSN requirement; the results should be applicable directly into the practice. The tasks to be tested are for example relocation of components, adding and modifying keepout areas, modifying circuit boards outline and thickness. All the tasks need to be tested with several different components and in addition it has to be considered that the tested change input may emerge either in the MCAD or in the ECAD tool. Moreover, within the testing changing points and the communication between the MCAD and the ECAD tool it should be noted that the designer need to have an opportunity either to accept or to reject the proposed change. Altogether there are numerous items to be tested and all the testing tasks are being followed up separately.

After some challenges with installing the licenses the project was started with self-introduction to the new tool by all participants. The representatives of PTC and Mentor Graphics organized an excellent live demo session of the tools; with the given introduction to correct approach it was a lot easier to start actual testing of the tasks. Also, in the demo session were looked through the restrictions of the EDMD tool so it was especially easy to rule out certain tasks that are not possible to solve with the tool at all. The project meetings were decided to be held every second week to follow up the progress of the testing and to solve together with PTC and Mentor Graphics possible arising problem cases.

The actual testing was carried out with the whole project team gathered in the same meeting room. It was considered to be the most efficient way of working as the communication was fluent and the problems were solved concurrently. In a normal working environment the tools allow simultaneous using in several locations and between separate design centers; the possible restriction results of limited number of floating licenses available.

The process of design change is similar in both collaboration tools. Basically, the proposed change request will be checked after which it will be either accepted or rejected and the response will be send back. Before the changes are being made, so called baseline including e.g. circuit board outline and components is being shared from one tool to another. After the both tools have the same baseline, only the needed changes are being sent and this makes the process much more fluent. This feature offers a great benefit compared to currently used IDF format were all the data need to be send in one file containing always the complete circuit board outline and component list. The changes are therefore difficult to locate and check; in the tested ECAD Expedition EDMD tool changes are pointed out with arrow (figure 9) and in MCAD Creo with color codes (figure 10).

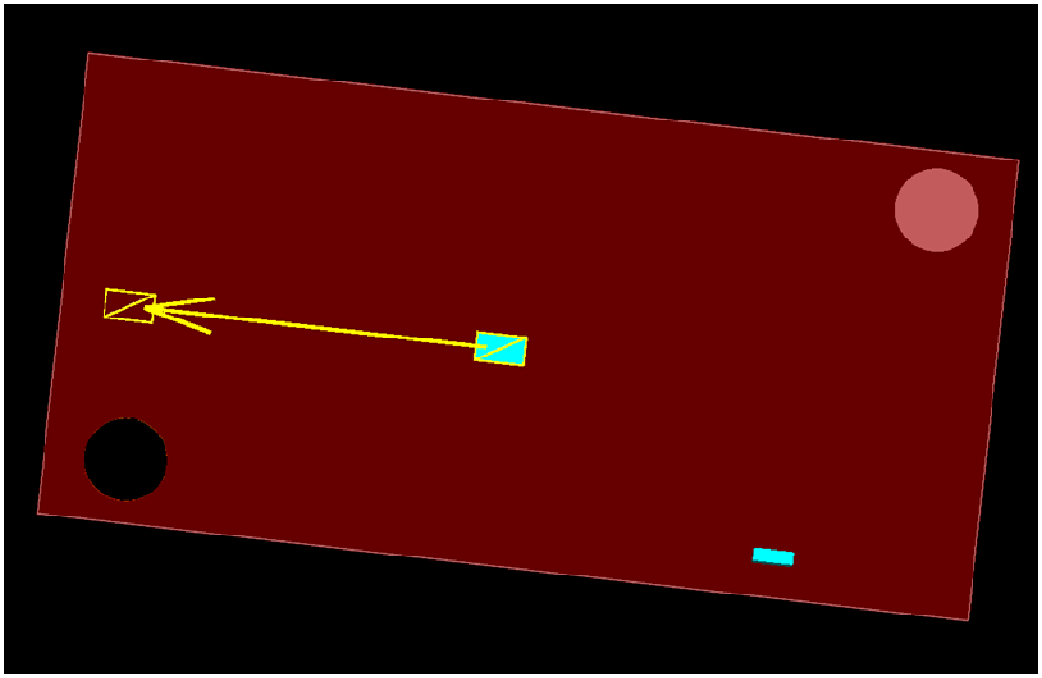

FIGURE 9 Component change in Expedition EDMD tool.

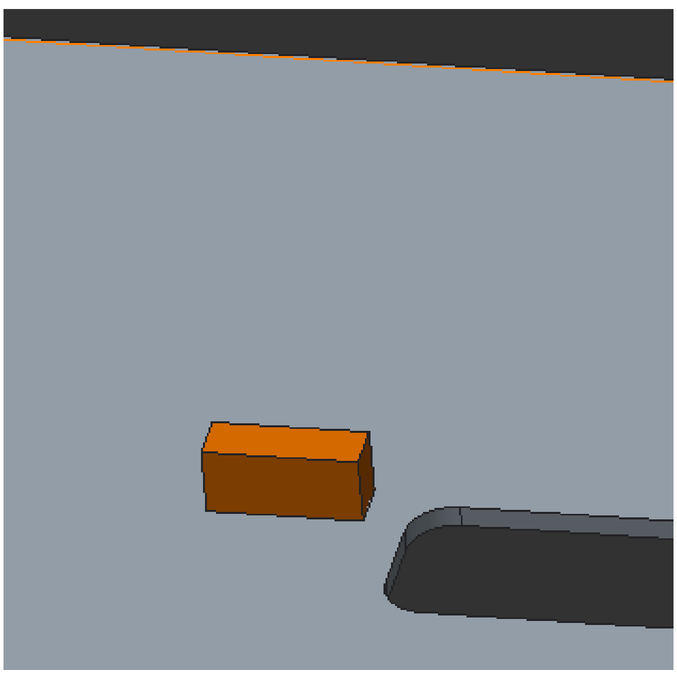

FIGURE 10 Component change in Creo EDMD tool.

2.10.2 Challenges

Software implementation projects usually have some difficulties and this project was not an exception. Part of the needed licenses was delayed and also installing the licenses was not completed as planned; therefore starting of the project was postponed. Nevertheless, the original deadline was kept which tightened the timetables. The project schedule of only three months was the main challenge and also limited number of testing personnel. The team members had their own projects to work with and it slowed down the tool development.

The design software, for which collaboration tool was intended, were rather recently taken into use so the team members had limited experience of working with the design tools. Some additional support from the software manufacturers was required in order to complete the collaboration tool testing in such extend than planned. There were also minor challenges to integrate two operating systems into one environment as MCAD is based on Windows and ECAD runs on Linux. It was decided to use solely Windows as it was an easier system to build up testing environment with. The system change was possible to perform even with project ongoing as Mentor Graphics Expedition supports both Windows and Linux.

Despite the technical challenges and the very tight schedule the project was completed timely mostly due to the excellent tool support and the active schedule management. Based on the experiences of the project it can be assumed that the possible tool implementation in the actual design environment will be challenging. Most likely the collaboration tool would encounter resistance of change as it would alter the ways of working significantly. The benefits of the new tool should be clearly explained and also the guidelines should be well prepared to ensure positive response.

2.11 The way forward

In case the collaboration tool is decided to be implemented throughout NSN's functions based on this pilot testing project, there will be a new testing project with wider scope. Most probably the testing would be performed during 2014 so that the actual implementation could take place in 2015.

The collaboration tools are under constant development at their manufacturers; both Mentor Graphics and PTC are going to release new versions during 2014. Both software will have good improvements in EDMD tools which were missed in the testing phase but some challenges will remain; few deficiencies considered critical will be solved in later versions. PTC, MCAD manufacturer, has indicated that in future Creo will support for example copper planes and layer stackup from ECAD. Mentor Graphics has also published future plans for renewed design software Xpedition, currently named Expedition. In Xpedition there will be a 3D component library with more exact models of components which improves greatly the visual review of designs. In addition the Xpedition will have a new feature for importing mechanic parts such as screws, heat sinks or even whole mechanic to layout design. Figure 11 illustrates the 3D view in the new Xpedition tool.

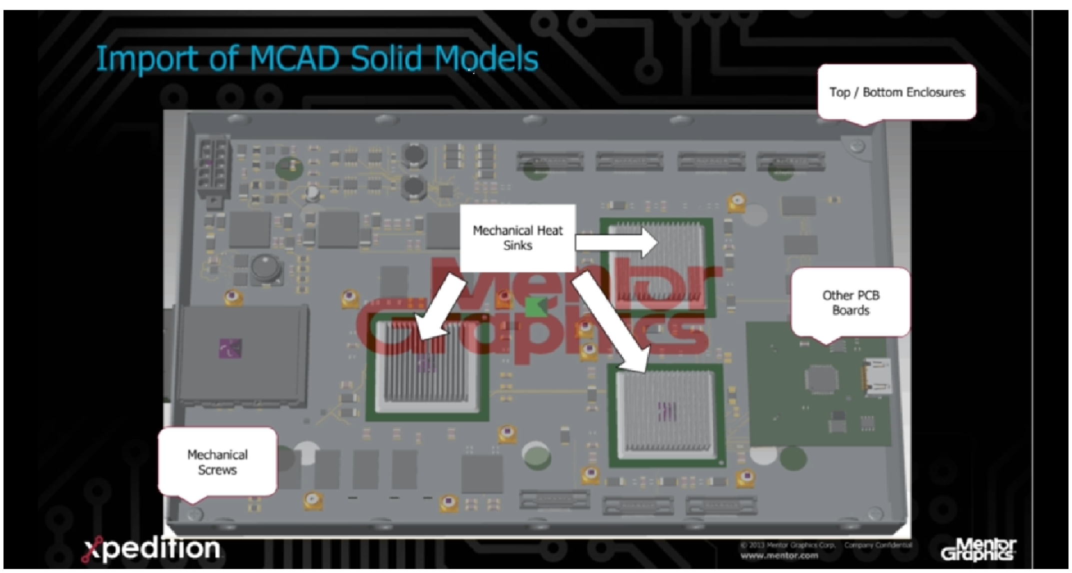

FIGURE 11 Mentor Graphics' Xpedition layout tool (16)

2.12 Results and conclusion

During the short testing period the EDMD proved to be a potential tool for improving co-operation between the mechanics and electrical design. The collaboration tool provides excellent information for PWB designer in the 3D format which was not available before. The designer can easily find possible error components or check correct disposition of components. The exact modeling of component has a great role in the whole design process and therefore it is highly important that also the 3D modeling is reliable. However, creating and supplying 3D models of components are not at software manufacturers' responsibility but those are provided by component suppliers. There is a need for better co-operation between these two supplier groups so that there would be more 3D models available; surely it would expand the usage of EDMD.

From mechanic design point of view, the EDMD also provides exact component models. Furthermore, the communication between mechanic and PWB designers improves greatly as it is continuous throughout the whole design project. For mechanic designer the EDMD does not offer other visual improvements of significant meaning.

The EDMD tool enables data transfer in IDX format which is much flexible compared to the current IDF format. A data file in IDF contains all possible information related to a layout design in hand; the IDX instead consists of only the changes designer has selected for transfer. This way the checking of the changes is much more fluent for designer receiving the data.

PTC and Mentor Graphics have a major role in creating new IDX format and the companies have also close co-operation in the development process. Therefore it is rather strange that the two EDMD tools are quite different; for example the change function and the related log data are processed completely different ways. Both the tool manufacturers should improve especially users' possibilities to track and manage the log data. Nevertheless, a major deficiency in both tools is a lack of design module off PWB planes such as solder mask.

The purpose of this pilot testing project was to gather and document relevant information of the collaboration tools to support the decision whether the tools should be taken into use at NSN. All the planned testing tasks were completed within the schedule; some of the tasks failed in the current version but were passed with workaround solutions. With some reservation the EDMD could be an excellent aid for PWB and mechanic design, providing that the tools are improved and developed further.

3 VIRTUAL PROTOTYPING

3.1 Problem statement

Virtual prototyping is focusing on reducing project cost and time, as well as improving quality. Currently the problem is inoperative discussion or communication between different designers or departments. The lack of fluent information flow weakens the interaction and creates ground for possible errors. The information gaps also cause delays or difficulties to react and repair problems. The sooner you are aware of the problem, the easier it is to respond with a correct action. Many times the amount and quality of the data is enough, but controlling the data is challenging. Each designer need to figure it out themselves what kind of data is needed by others and when it should be released. It requires well-instructed teams in order to have a fluent design process with the current tooling.

3.2 Background

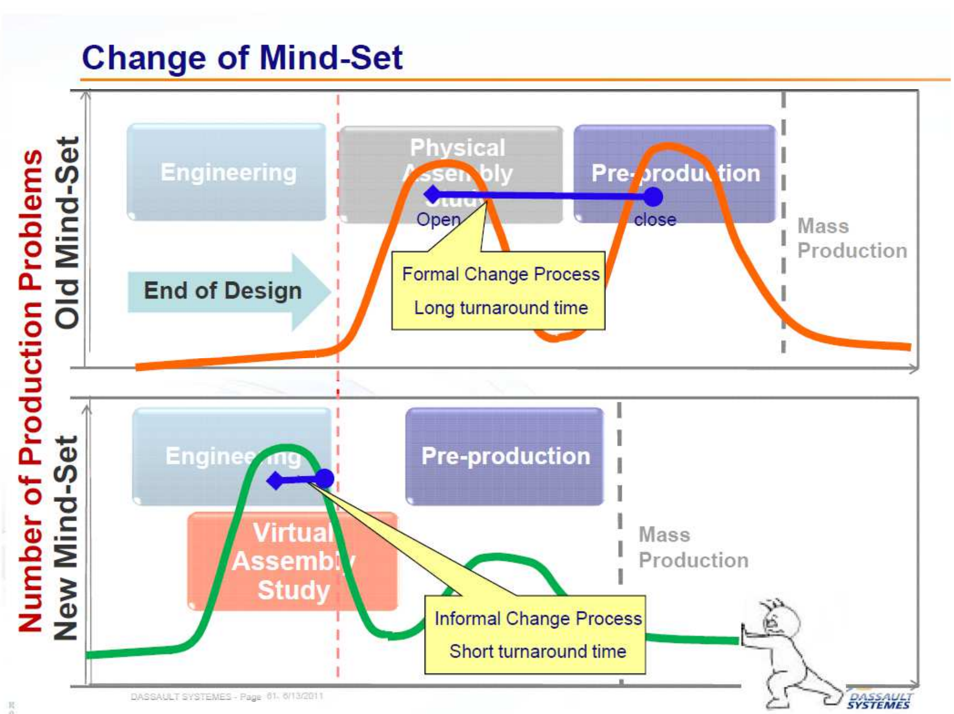

FIGURE 12 Differences of old and new mind-set (17 p.51)

Figure 12 is a good example of needed changing of mind-set. This is actually one of the main focus points in virtual prototyping; how to turn the way of thinking, to start operating and simulation in more early phase. In the old mind-set failures are encountered in pre-production and the response time for corrections may be very limited before mass production phase. Usually the pre-production is carried out in hast; product introduction, problem solving and documentation take a lot of time. New mind-set aims to shorten the process turnaround time. Through a proactive mind set and virtual prototyping more failures can be found earlier than in physical assembly and furthermore, there are more time to respond in virtual prototyping phase.

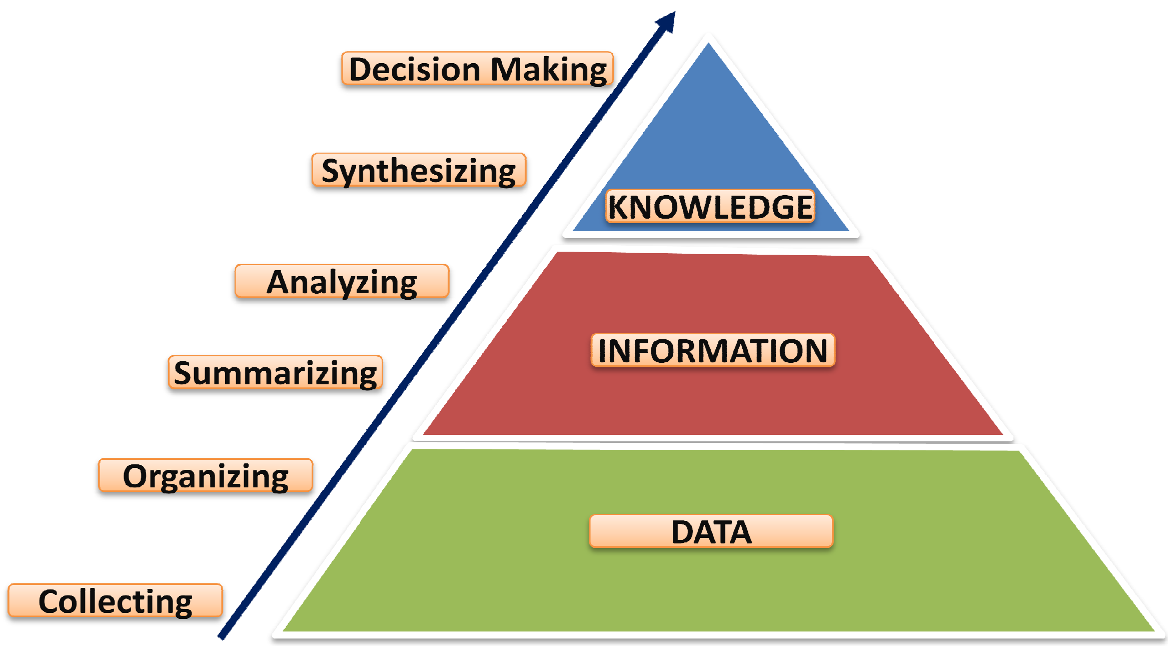

FIGURE 13 Knowledge Management (18 p.15)

Figure 13 presents a diagram of knowledge management. At first the data will be collected from various simulations after which the gathered data will be filtered to sort out the relevant parts. The information considered necessary will be analyzed further for gaining understanding of possible issues or problems at hand. Finally, a decision can be completed of actions to be taken; this is the basic process of the data utilization in virtual prototyping.

3.3 Current design flow

In the current process flow with the old mind-set the loop of engineering, testing and analyzing results continues as many proto rounds as needed. It is relatively common that the product in the design process may be behind schedule and it proceeds to production unfinished resulting to a situation that the product faults are being found only in the pre-production.

Typically in the starting phase of a project the basic data needed is already available but gathering and storing it in a same place is quite difficult, especially when the data should be accessed by many. Controlling the data is a very common problem within larger organizations. Also, manual analyzing and selecting relevant data may be difficult to organize in a way that it serves all functions participating in the project. In worst case the data is being processed in haste as some decision needs to be made before proceeding.

Briefly, all the needed data and know-how is available but the utilization of those is a bottleneck. Practical and controlled collection of data, fluent sharing of knowledge and changing processes into a bit more anticipatory planning are clearly targets to aim for and virtual prototyping could be just the right tool.

3.4 Existing solutions

The basic ideas behind virtual prototyping are not new or unique; for long time there have been solutions for saving product costs and increasing quality. Some of the methods have proven to be successful and here are few examples; it is good to remember though that companies do not present their latest innovations.

Toyota has started its own virtual prototyping model in 1996 and here is couple of examples of their flow. Basically, instead of having clearly separate phase of engineering and production, Toyota has involved production personnel in early phase in engineering process by using a virtual assembly review. It is easy to understand the benefit of virtual testing environment to be used, as the tests and reviews can be repeated quite easily after engineering changes.

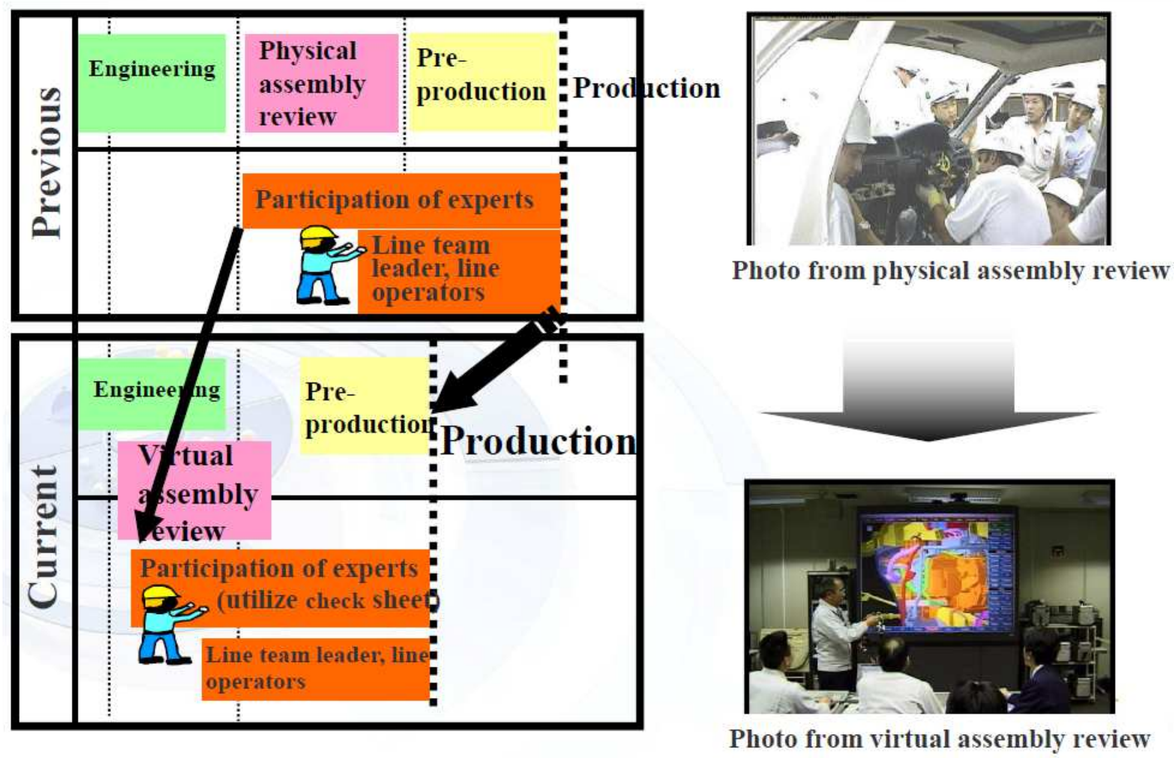

FIGURE 14 Previous design flow vs virtual assembly review (17 p.29)

In the car industry physical assemblies are complex and expensive; also modeling all parts are challenging. By using the virtual assembly review Toyota has fasten engineering process flow and figure 14 presents clearly how much faster products are ready for production than earlier.

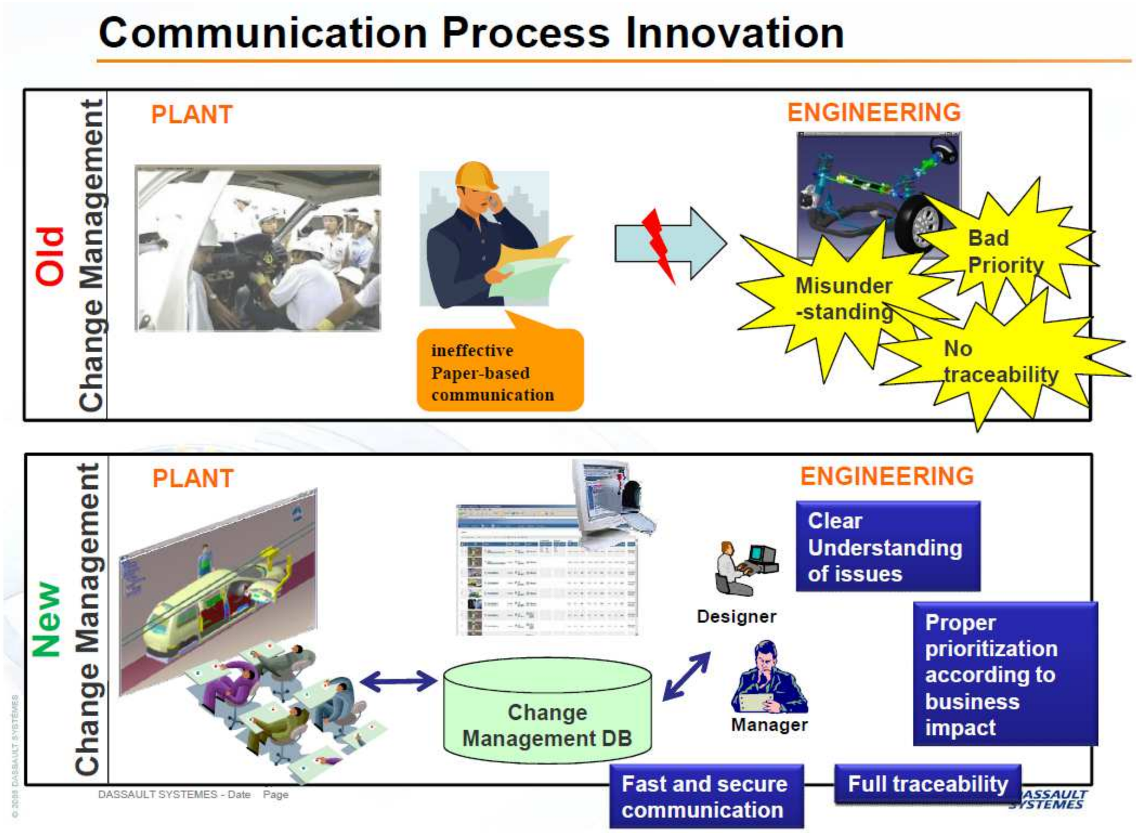

FIGURE 15 Communication has an important role in virtual prototyping process (17 p.36)

One of the main reasons to start using the virtual prototyping at Toyota was a need to improve communication as presented in figure 15. Overall documenting engineering process was ineffective and time consuming; confuses were common due to misunderstandings and lack of traceability.

In addition of easing engineering, virtual prototyping is a good tool for the process management as well. A process planning in virtual prototyping process can be started in much earlier phase than with old style physical modeling. The process planning is able to use the same virtual process data as other functions and hence there are much more time to react on the needed changes.

Dassault Systems' DELMIA (figure 16) is one of the virtual prototyping software. Toyota has chosen it as their tool and it covers all the engineering and production related functions.

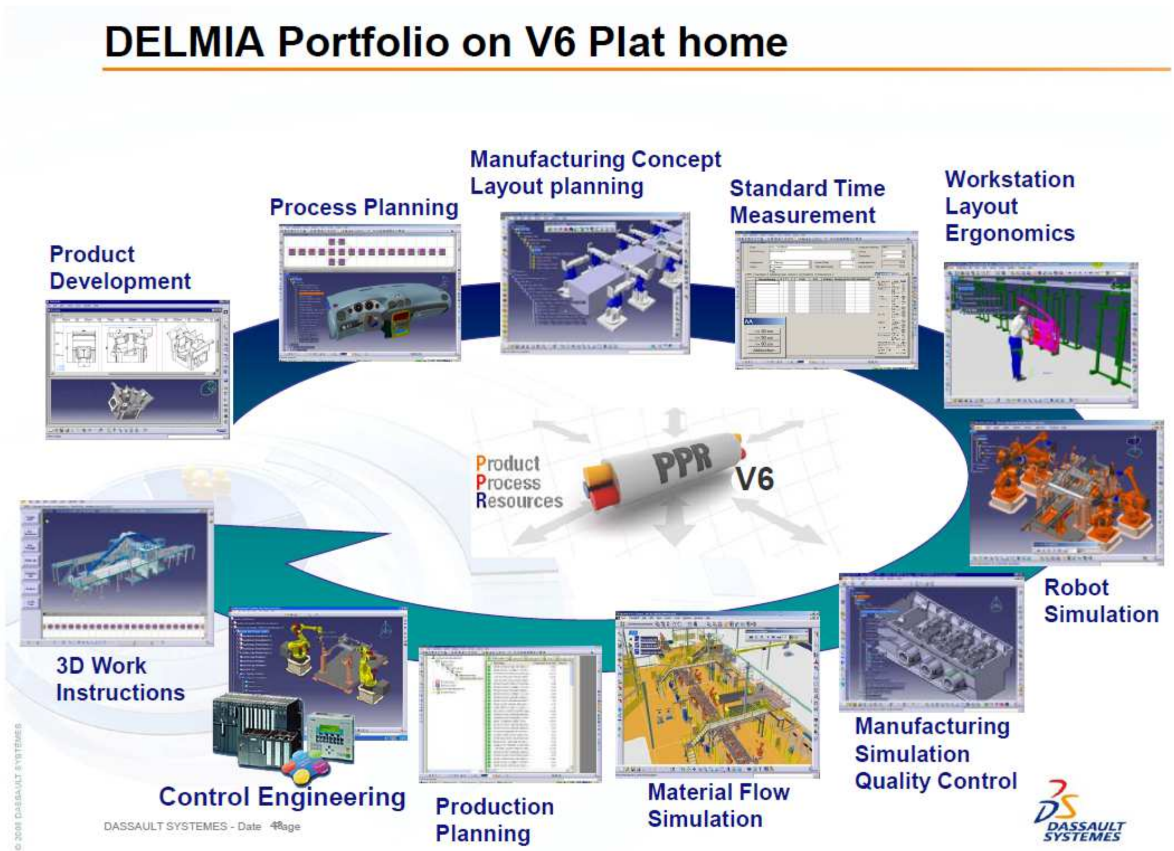

FIGURE 16 DELMIA process by Dassault Systems (17 p.46)

Obviously, the utilization of virtual prototyping in such extent has required massive investments both in financial and in effort sense. However, shortening of the time required to get new models to markets is valuable advantage especially competing within consumer products and therefore also e.g. General Motor is using the virtual prototyping. Also many other European car manufacturers utilize the virtual prototyping for example in crash simulations.

Reasons for implementing virtual prototyping as a part of operational process are more or less same regardless the size or industrial field of company's business. One solution is to choose certain virtual prototyping software, have it customized and implement it to be standard part of company's processes, as Toyota has done. The other option is to use more readymade solutions which are also widely available on the market. In practice this usually means acquiring of subcontracting and this might not be so time-saving solution but it does not require heavy investments either.

Ansys is one of the leading software manufacturers providing tools for virtual prototyping and data management. Compared to Dassault Systems used by Toyota, Ansys' solutions are lighter.

> ANSYS Engineering Knowledge Manager™ (EKM) is a comprehensive and intuitive foundation for CAE data/configuration management and automation. With this tool, you can accommodate critical needs within your global product development process, from integration with PLM systems (CAD/PDM) and execution (HPC) to collaboration and communication. Right out of the box, EKM is tightly coupled with ANSYS products. You can easily integrate it with other simulation codes, including legacy and commercial off-the-shelf software (19, p2.)

A company called Convergentia is providing a full set of simulation surroundings and as they describe it in their brochure: "World's First Virtual Prototype Factory -Integrated Simulation Solutions based on customer requirements" (20, p1). At the simplest they perform a separate simulation and analyze the results for customer for further actions. Convergentia can also play a significant role in customer's project by offering various simulation models and expertise e.g. in mechanics and antenna development as presented in figure 17.

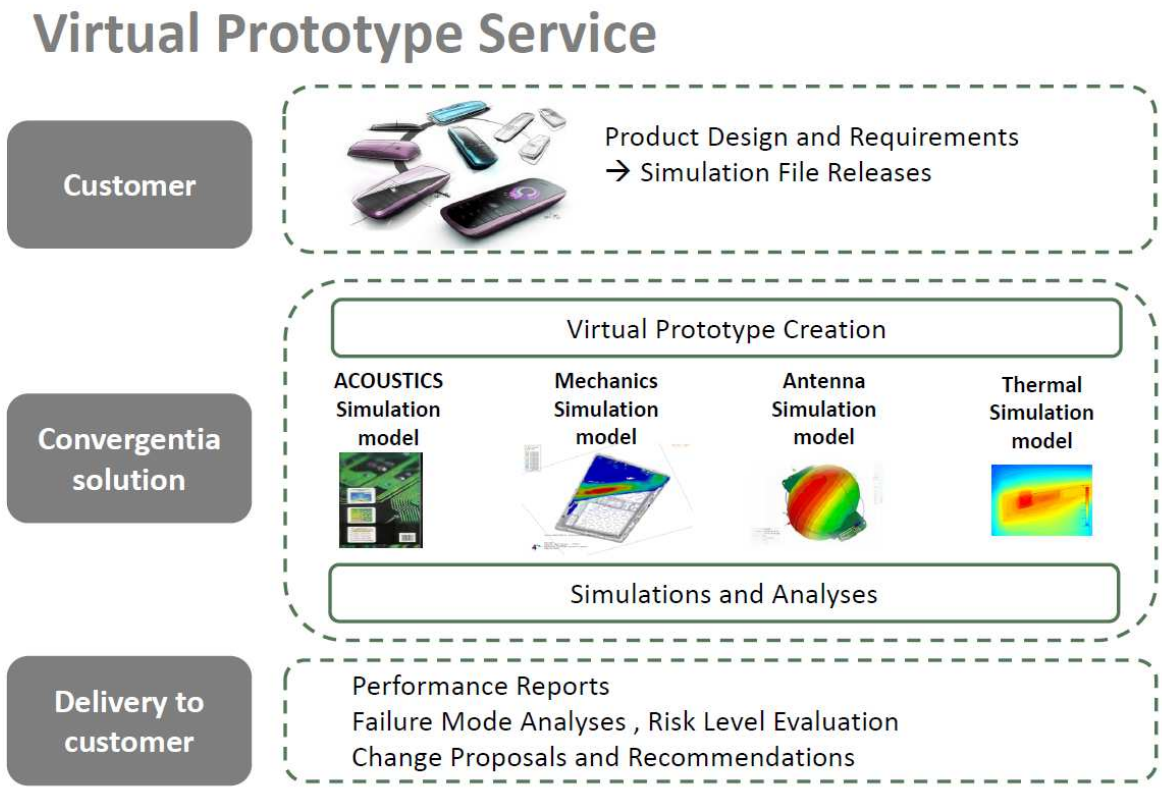

FIGURE 17 Convergentia's Virtual Prototype Service(20, p3)

Figure 18 presents Convergentia's concept of process flow by utilizing virtual prototyping. Customer provides a product design to be simulated and specifications for needed tests. Convergentia can also analyze customer's own simulation results; after the analysis phase Convergentia returns the results and their suggestions to the customer. There may be need for several simulation and analysis rounds while determining product maturity level.

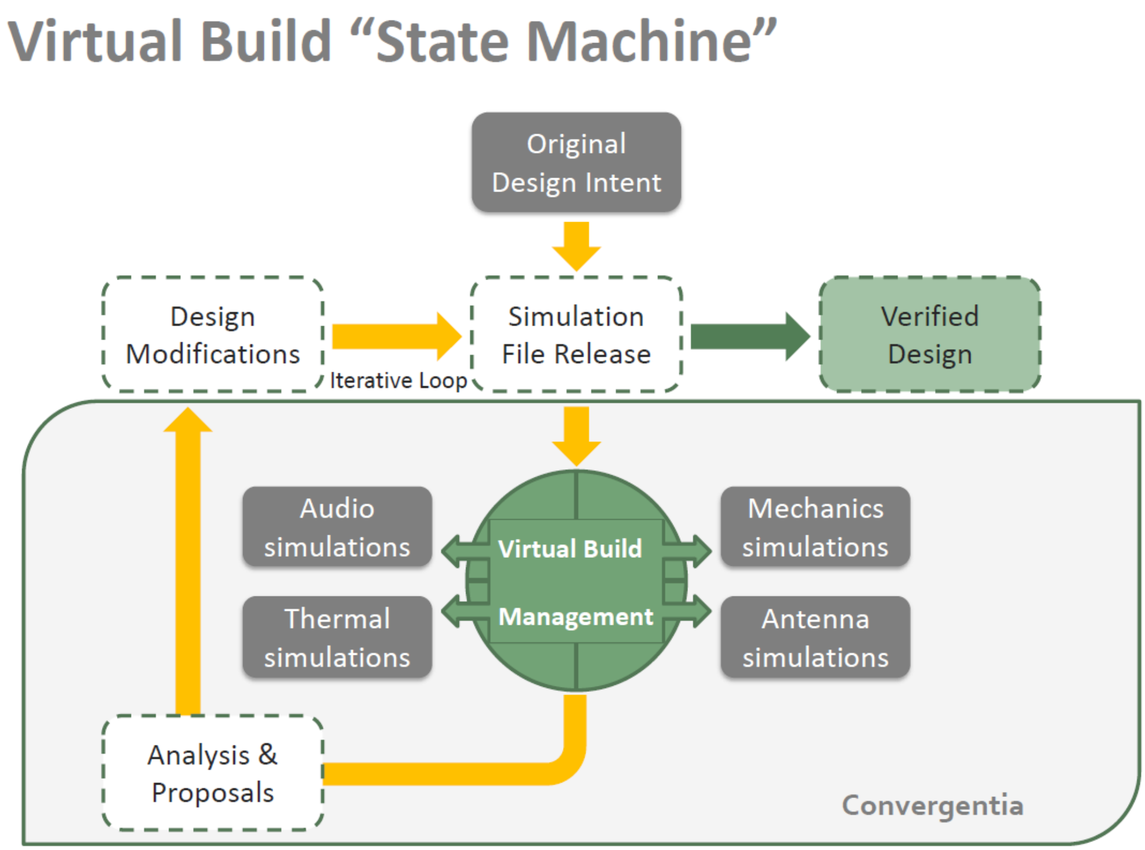

FIGURE 18 Convergentia's State Machine (20, p6)

For the study Convergentia's Director R&D operations Jukka Solla was interviewed and he raised few issues to be noticed from customer's point of view when using their services. The project costs in the beginning might be higher compared to a in-house R&D project but in most cases the total project costs end up to be significantly less. The project process will remain same so it can be easily taken as a standard part of customer's own process and possible threads are minimized by using the same approach at all time. Solla also pointed out that both time and costs can be saved with an upfront project schedule as there is more time to react on and correct possible faults.

3.5 Virtual prototyping modules

There are numerous software available for virtual prototyping, from various manufacturers. When selecting suitable tools for a certain project, it is worth considering which modules should be used. The existing system environment and for example a number of possible users may have an impact on the range of modules to be used.

Mechanic design has a major role in virtual prototyping. The mechanic data is required in every simulation module and especially the data of circuit board modeling is needed in PWB design. Usually the data is being transferred in the DXF or IDF format depending on the content of the data and the receiving tooling. Mechanic parts have quite long lead times and currently the completion of mechanic design defines the project schedule for whole team.

PWB design provides data for PWB SI (Signal Integrity), PI (Power Integrity) and PWB EMC (Electromagnetic Compatibility) simulation. Usually the data is being transferred in an ODB++ format as it is widely supported within simulation tools. From the mechanic tool the data of PWB outline is transferred in DXF or IDF format. Along progressing in the design, the data from completed sections is being transferred for simulation purposes. For example, the PWBs have a shorter lead time than mechanic so it is possible to proceed with design while waiting for rest of the parts.

Thermal simulation includes for example measurements of heat conduction and transfer, air pressure and flow. Usually the thermal simulation requires a long testing period as the mechanical design can be in very early state when the first simulation rounds are being started. A tool called Icepak by Ansys is suitable for simulating thermal features of for example components and circuit boards. Figure 19 presents a view over test result in Ansys' Icepak simulation tool.

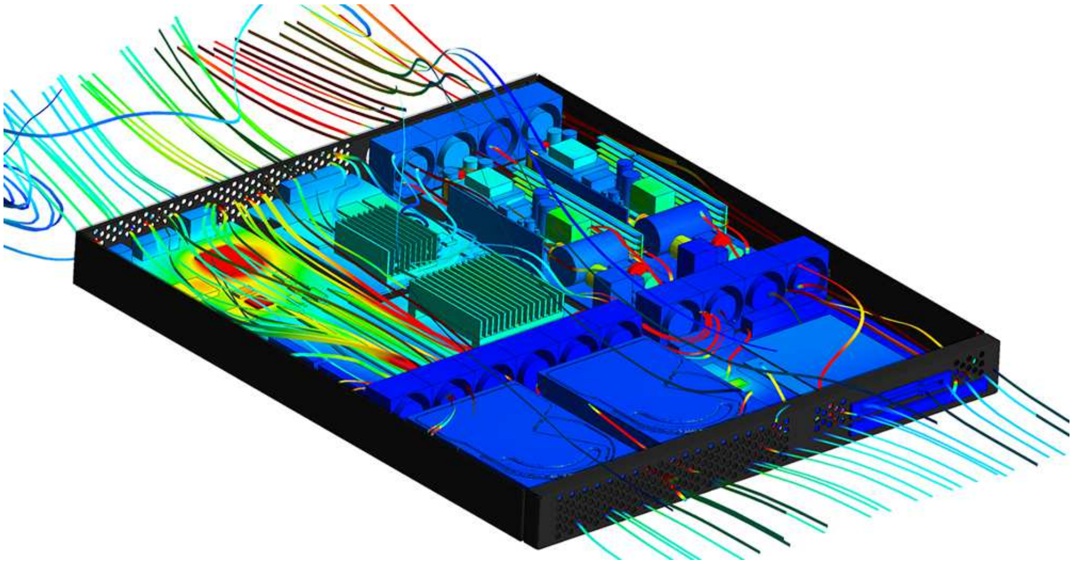

FIGURE 19 Ansys' Icepak simulation tool (21)

EMC simulation is currently considered rather important from product quality point of view. Possible failures caused by the EMC are tried to be discovered and removed already in an early phase of the project. Suitable tools are for example Microwave Studio and Cable Studio by CST which can also be used for 3D simulations. Simulation objects may be e.g. tightness of mechanical design in the Microwave Studio and cable interfaces in Cable Studio. There are also some additional features available for Microwave Studio, for example a TLM Solver for lightning simulation. Figure 20 shows an example of simulation possibilities offered by CST Microwave Studio.

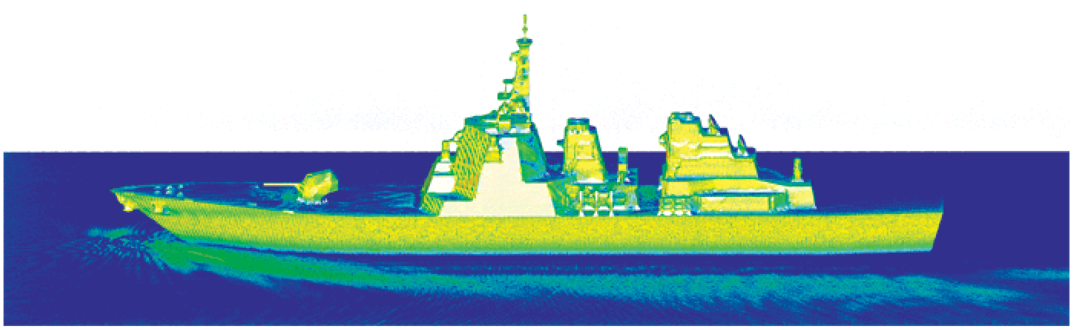

FIGURE 20 A simulation view in CST Microwave studio (22)

PWB simulations can be divided into three sections; SI (signal integrity), PI (power integrity) and PWB EMC simulation. All these simulation phases have a significant role in the design process and hence there are separate simulation software for each segment.

The simulation tool for signal integrity is called Hyperlynx by Mentor Graphics, presented in figure 21. With the tool it is possible to measure a quality of signals even before circuit board has been designed, presuming that some basic specifications are available. The simulation will be repeated after the circuit board design is completed and these results can be then compared with the first simulation outcome.

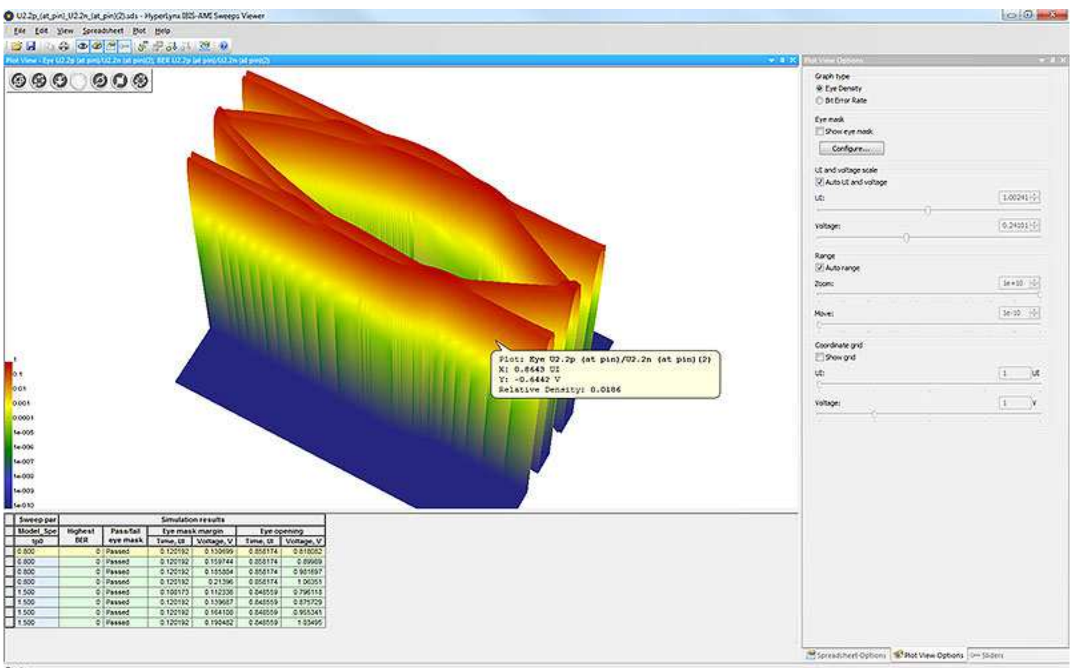

FIGURE 21 Mentor Graphics Hyperlynx 9.0 SI (23)

Power integrity simulation enables a measurement of DC voltage and a thermal analysis for circuit boards and critical components. In addition possible simulation targets are IR drop, density of current and other thermal simulations. Cadence's Sigrity PowerDC (figure 22) is a suitable tool for this simulation and in addition Cadence offers a PowerSI tool for analyzing for example frequency domain power and signal integrity, verification of components' location and evaluating electromagnetic coupling between geometries. There is also available Mentor Graphics Hyperlynx PI with same kind of features (figure 23). Furthermore, Cadence has developed a tool called OptimizePI for analyzing the optimal number of components for gaining cost efficiency and simplified design.

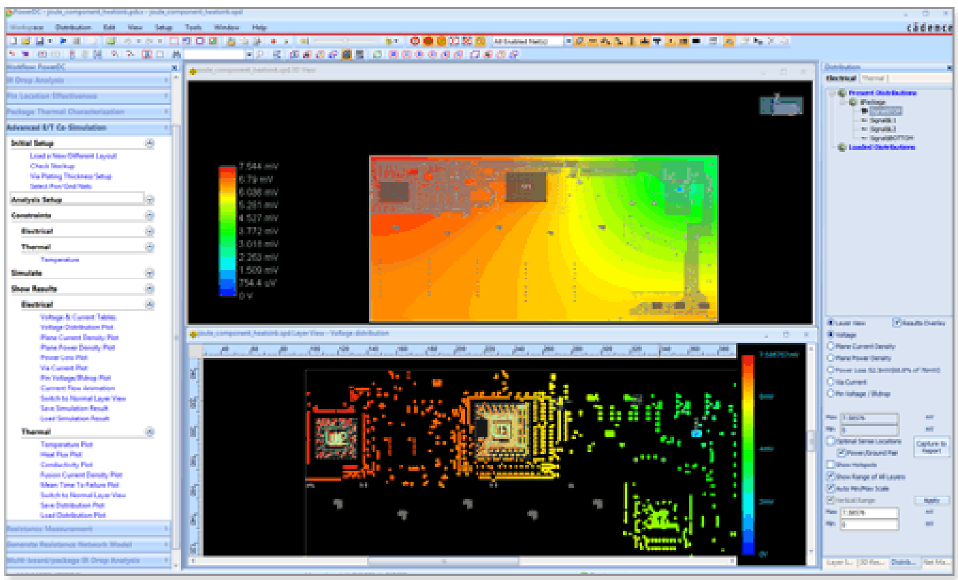

FIGURE 22 Sigrity PowerDC simulation tool by Cadence (24)

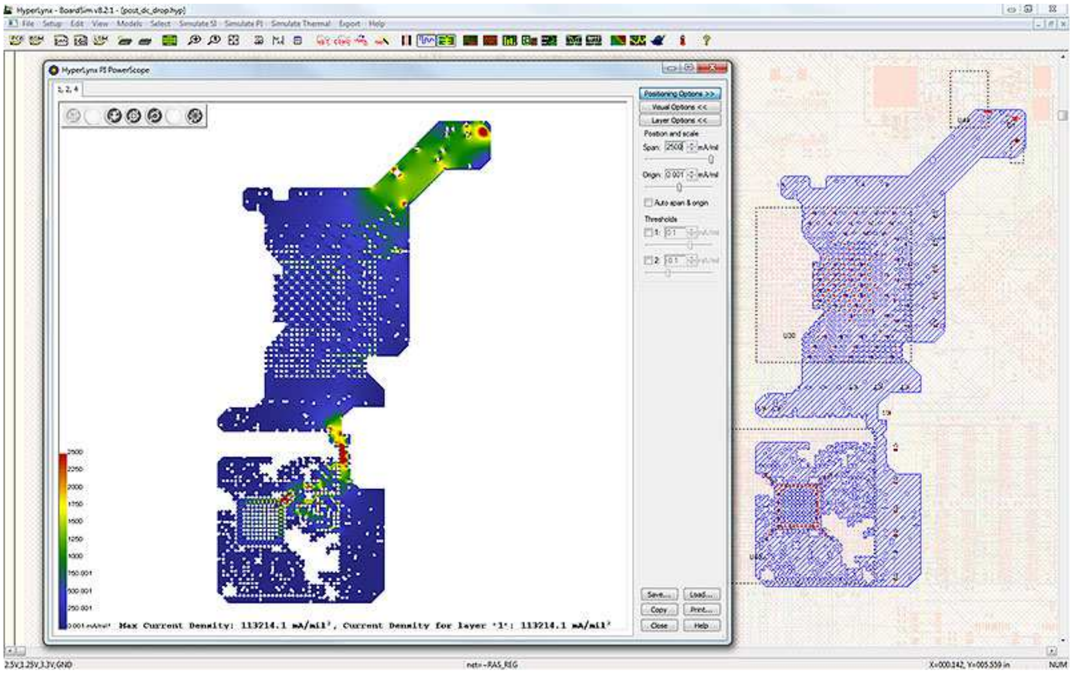

FIGURE 23 Hyperlynx 9.0 PI by Mentor Graphics (23)

PWB EMC simulation utilizes same tools than PWB PI simulation, e.g. PowerSI by Cadence. Useful simulation results are for example circuit board resonance, impedance and coupling of traces and interference radiation. In addition Microwave Studio by CST (figure 24) can be used to perform a 3D EM simulation for time and frequency level. The CST's tool enables more detailed simulation and exact analysis of certain part as the simulated object can be processed in several parts.

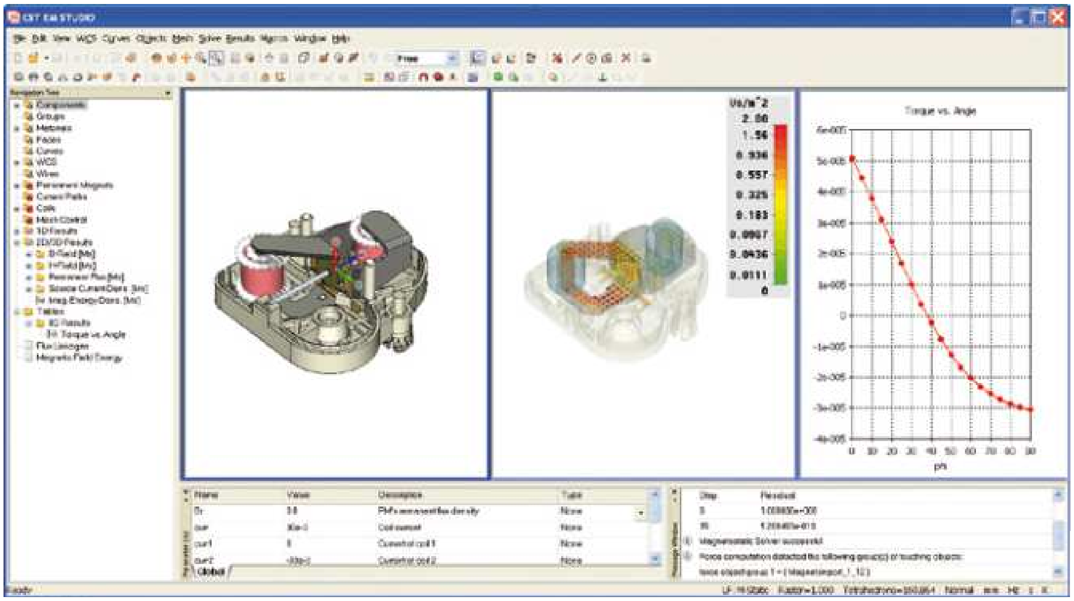

FIGURE 24 CST's Microwave Studio (25, p2)

In addition of the design phase, the simulations are used in the production process as well. A simulation tool called DELMIA by Dassault Systems analyzes cabling, usability and manufacturability; the tool has modules also for Assembly Simulation Engineers, Manufacturing Planners and Ergonomics Specialists as showed in figure 25. All production simulations target for improving production efficiency and preventing possible failures.

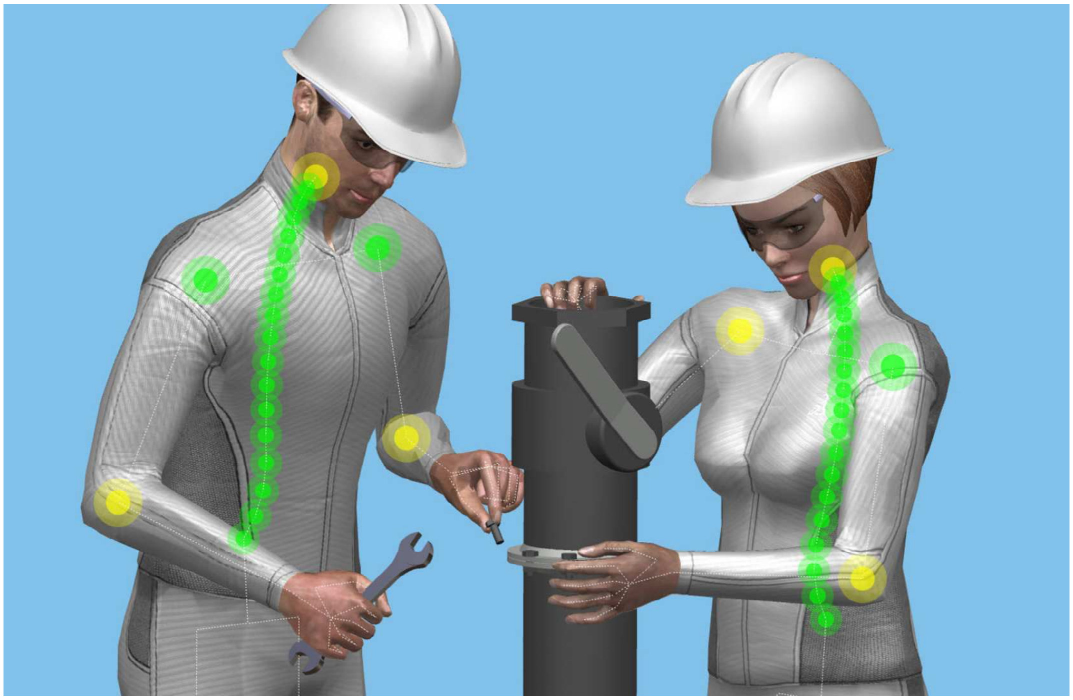

FIGURE 25 DELMIA Ergonomics Specialists simulation tool by Dassault Systems (26, p1)

3.6 Data management

Data management has a significant role in the simulation process. The simulation result data and related documents usually require plenty of storage space and at the same time the information should be available for several users. This might form some challenges especially in projects shared with several locations; the version control lies on each designer and e.g. email is too size-limited tool for communication. Nowadays there are commercial solutions in wide range for creating company's own cloud services but naturally this will require some dedicated resources for maintenance. It is also possible to use ready-made tools with a fixed data management structure; these are offered e.g. by Arena and Ansys.

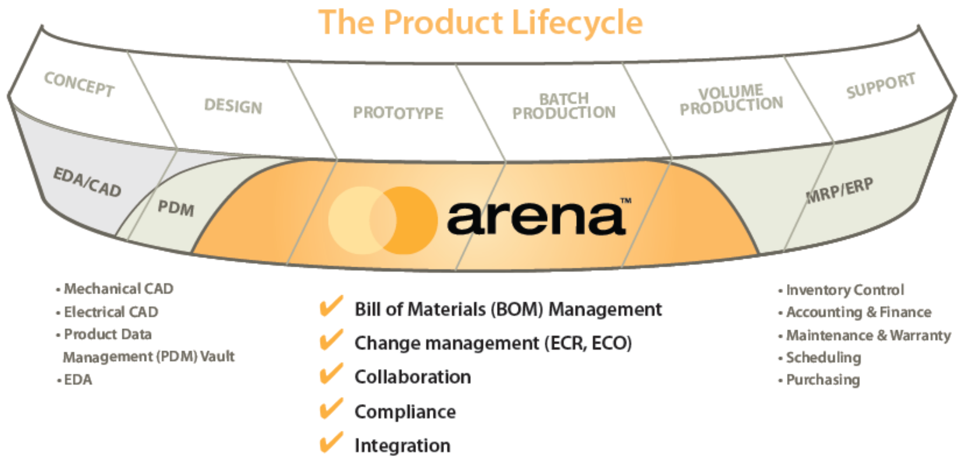

FIGURE 26 Arena solutions from design to product (27, p4)

> The innovative designs in the form of drawings, specifications, schematics and layout will be transformed into great products only after many iterations of changes have been made, components have been sourced, rigorous tests have been performed, compliance requirements have been met and products have been made and packaged (Figure 26). Therefore, in addition to design files, product information—such as BOMs, items, costing information, engineering change orders (ECOs), approved vendor list (AVL) and compliance status—is required to transform designs into manufacturable products. While PDM tools are sufficient for managing engineering design files, they are not equipped to facilitate the process of taking the product information from creation, through numerous changes by global cross-functional teams, and all the way to manufacturing (27, p3.)

A tool by Arena Solution is created for connecting designing and production functions. These features and the cloud services could be utilized in the virtual prototyping at NSN.

The other alternative solution is Engineering Knowledge Manager, EKM by Ansys.

> ANSYS EKM is the framework for making quicker and informed CAE decisions. Best-in-class search, meta-data extraction and reporting capabilities allow initiation of new design projects based on knowledge learned from previous design attempts. Users have access to a host of project- and content-management capabilities de-

signed specifically for work-in-progress and archival CAE needs (19, p2.)

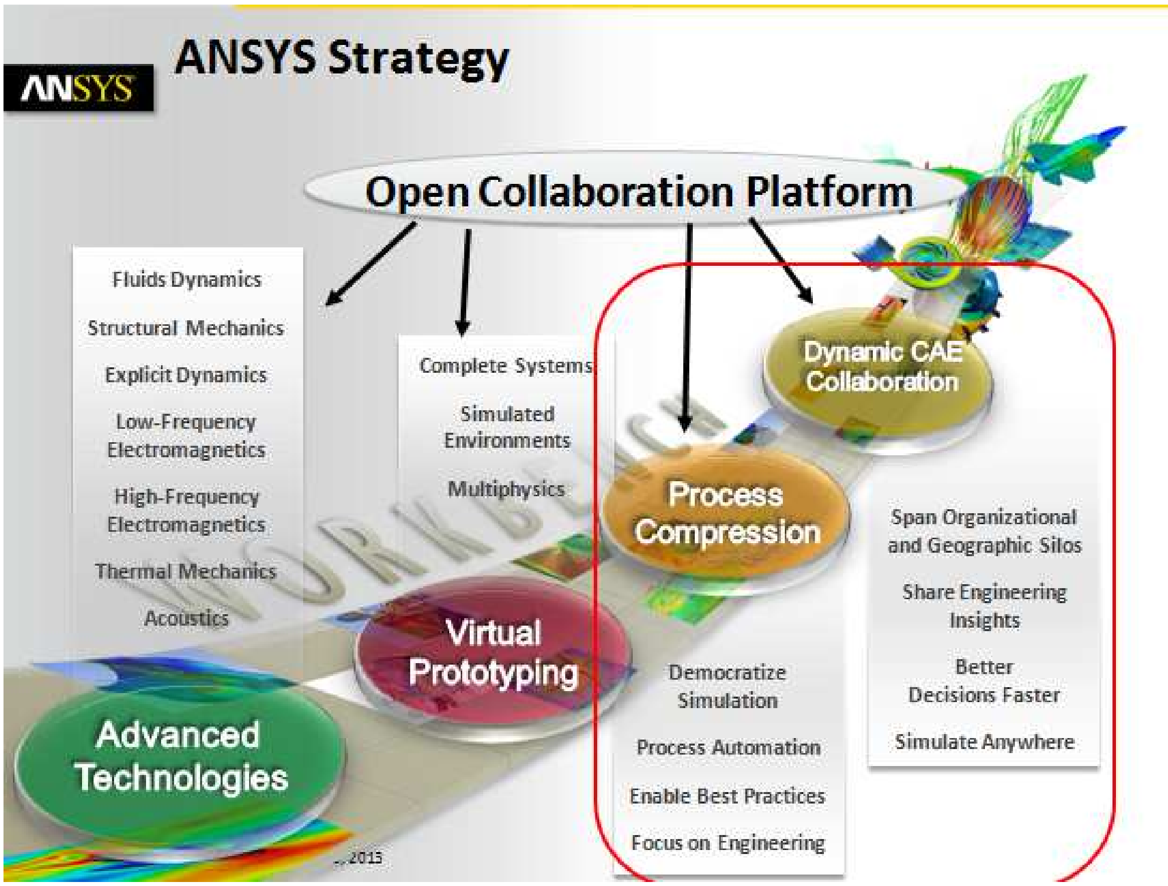

FIGURE 27 EKM by Ansys (18, p.12)

The EKM by Ansys focuses on data management and scalability enabling multisite team working as presented in figure 27. Both functions are very important in the virtual prototyping process as currently searching the data takes too much specialists' time and also it is common that few sites work on same design project.

3.7 The way forward

Based on this pilot project, it can be stated that virtual prototyping has clear benefits and potential. It would be sensible to implement it at NSN within next project starting even if there will be need for further development to adjust virtual prototyping into NSN's practices. Integrating the new way of working will be challenging as it will cover wide range of functions from data management to communication on many levels. One of the major challenges will be training personnel and instructing the usage of virtual prototyping in such way that it will serve the whole process in optimal way.

Before implementing virtual prototyping it should be decided which functions will be included in the project and what kind of simulation is required. There are existing models of approach for the virtual prototyping, but it is advisable for every company to discover suitable practices of their own. For easier start the virtual prototyping can be integrated into existing process even though in practice it will trigger need for continuous development within R&D functions.

Data management is also one of the issues to be solved before implementing any tools. The options are either to have own data storage system or to use some ready-made solution; both methods have their advantages and weaknesses. Own data management system is naturally customized according to NSN's needs but on the other hand requires constant maintenance resources. On contrary, the commercial data storage tool is more easier to maintenance but for sure some compromises must be done with the tool features and hence usability.

Starting to use the virtual prototyping requires some practical preparations such as data management and user training. Running projects with the method will get easier over the time but it should be noted that the virtual prototyping serves well in projects of certain size. It might be too heavy for small projects but on the other hand, complex and massive projects may be difficult to control as one trough virtual prototyping. An optimal virtual prototyping project consists of development work of single clearly specified object.

The virtual prototyping is rather new procedure at NSN and there are only limited experiences of usage. It has been implemented into few projects and the feedback has been positive. So far the greatest benefit has been a new meeting practice for problem solving in which the experts of all functions participate. This way the project team members get to know each other and they learn to understand the whole project. In the meetings and in virtual prototyping in general team members can share their expertise and in many cases new points of view may help to solve problematic issues.

4 CONCLUSION

The thesis concentrated on studying two possible methods to improve the NSN's product development process. A new software tool called EDMD was trialed in collaboration with the current design tools and virtual approach of prototyping and simulation was tested with a real product project. The purpose of these tests was to define possible advantages of the tools considering the NSN's design environment.

The EDMD collaboration software proved to be a rather potential tool for improving communication between the mechanic and electronic design phases. Currently data the transfer is quite cumbersome and hence changing the information during the design processes is insufficient. The possibility to flowing data transfer enables more fluent project working and may even shorten the project duration. Another clear advantage of the EDMD tool is its visual functionalities; the designs are easier to perceive with the 3D modeling and most likely this will also decrease the number of human errors. Finally, as an additional module to the existing design software EDMD tool should be simple to implement but clearly it still requires further development. During the testing few significant deficiencies appeared with the software's basic functionalities and the problems remained unsolved by the software suppliers. Nevertheless, both the suppliers have indicated that there will be new versions released during 2014. At this stage, it must be concluded that the tested version of the EDMD tool is not yet suitable for NSN environment.

Virtual prototyping is not only a software or a tool to be implemented but a new approach to the way of working. The results from the test project were promising but it will take years to learn the true benefits of the practice. The main observations of the test project were improved communication of team members and better utilization of the existing simulation tools. Based on these it could be assumed that in longer run the virtual prototyping could produce cost and time savings; at its best the virtual simulation could replace the usage of physical prototypes. Implementation of virtual prototyping requires strong commitment from project team members to really change the ways of thinking and hence it might encounter resistance among designers accustomed to old practices. Despite of the possible complications with getting started, virtual prototyping is definitely recommendable. Especially the concept of project meetings and information sharing was considered useful by the team members of the test project. Overall, concentrated data management has an important role in virtual prototyping since simulation results should be easily accessible by all project members. It can be summarized that the most relevant benefit of virtual prototyping is increased understanding of whole project process and its target by the participating employees; the actual measurable results may be difficult to gather.

The studies performed for the thesis provided adequate answers to the objectives set by NSN. The testing period could have been longer but the findings are considered sufficient in order to proceed with resolution in the current situation. Both the tools are very interesting from the product development's point of view and most likely these topics will be under further action at NSN in the near future.

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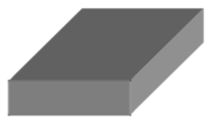
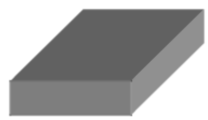
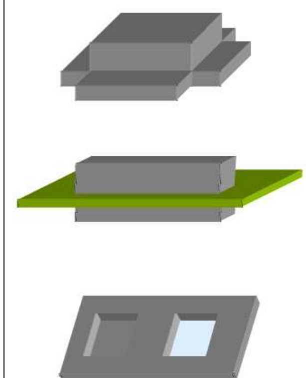
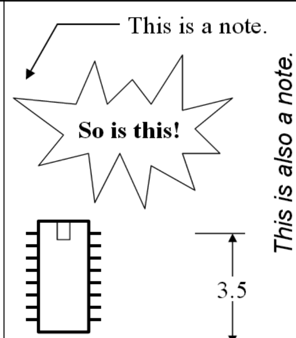
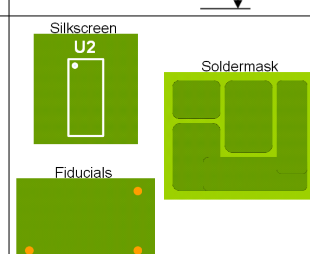
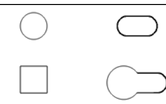
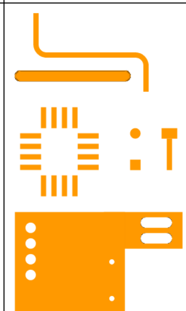
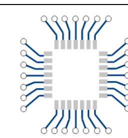
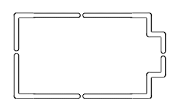
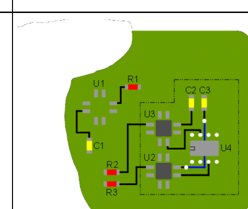
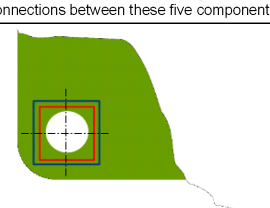
APPENDIX

IDF Overview

	IDF2.0	IDF3.0	IDF4.0
Data Format	DIP_8 PN-2245-D U1 100.0 600.0 270.0 TOP PLACED	DIP_8 PN-2245-D U1 100.0 600.0 0.0 270.0 TOP PLACED	Electrical_Part_Instance (Entity_ID (#3003), Part_Name ("DIP_8"), Part_Number ("PN-2245-D"), Refdes ("U1"), XY_ Loc (0.1, 0.6), Side (Top), Rotation (270.0), Mnt _Offset (0.0, 0.0)); /* End Electrical_Part_Instance */
Component Shapes			
Component Instances			
Annotations	X	This Is a Note	
Graphics	X	X	

Holes	 Attributes include: - Plating status - Assoc. comp. inst. (explicit)	 Attributes include: - Plating status - Hole type - Owner - Assoc. comp. inst. (explicit)	 Attributes include: - Plating status - Hole type - Owner - Layers spanned - Assoc. net - Assoc. comp. inst. (implicit)
Conductors	X	X	 Traces Pads Filled Areas
Footprints	X	X	 Component pads, breakout traces, via holes, and reference designator Board milling cutouts (in panel) 
Sublayouts	X	X	 Sublayout includes component instances U2, U3, U4, C2 & C3, plus the routing connections between these five components.
Figures	X	X	 Figure Representing: - Mounting Hole - Placement Keepout - Routing Keepout - Annotation (Centerlines)

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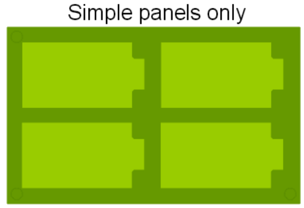</td>
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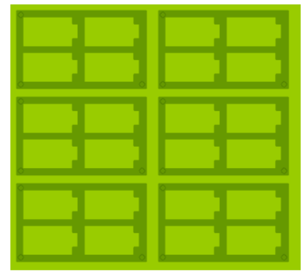</td>
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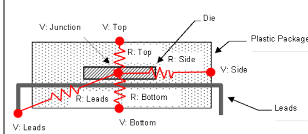
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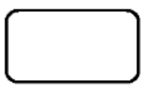
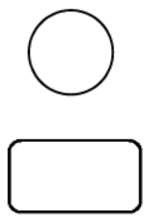
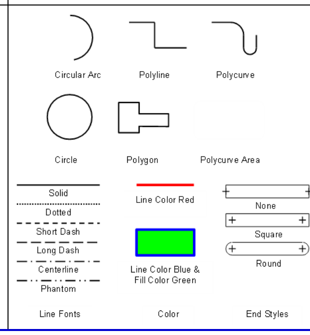
<td></td>
<td></td>
<td>
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