Disruptive Adaptability:

A Case Study in a Product Development Organization

by

José Guillermo Saavedra Román

B.S. Mechanical Engineering, Universidad Nacional Autónoma de México, 2006

Submitted to the System Design and Management Program

In partial Fulfillment of the Requirements for the Degree of

Master of Science in Engineering and Management

at the

Massachusetts Institute of Technology

June 2016

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Signature of Author..

System Design and Management Program
May, 2016

Signature redacted

Certified & Accepted by: ....

Patrick Hale
Thesis Advisor
Executive Director, System Design and Management Program

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Abstract

Enhancing the practice of Product Development has been addressed in multiple works and published in documents of all kind ranging from theses and consultancy studies to papers in specialized journals. Regardless of the focus, either on processes, tools, methods or organizational design what is common is a reactive –*"gap filling"*—approach.

In this work I propose that enhancing the practice of product development is better achieved when it is addressed from a holistic perspective in which either the improvement, optimization or enhancement of the product development practice is in essence an adaptation of the product development organization. Seeing the practice of product development from the *adaptability lens,* allows us to create enhancements that go beyond the traditional *"gap-filling"* approach of fixing issues using information from the past, and opens up a broader –yet richer—set of alternatives to design improvements that not only prevent issues to occur but that also are meant to *change the game.*

The main focus of this work is the design of a *disruptive adaptation* for Ford Motor Company Product Development Organization focused on its capabilities for the development of *in-vehicle features* which are instrumental in the customer experience that is delivered by Ford automobiles. This design was developed following a *systems thinking* approach for large complex systems and is aligned to Ford Motor Company objective of changing the way the world moves. The design concept for this *disruptive adaptation* focuses on elaborating a desired future state of the capabilities to develop an unparalleled customer experience in Ford vehicles. It also considers the future context of a platform-based business model where the automobile is the platform. As starting point, I researched the current state of Ford capabilities for the development of in-vehicle features and realized that the Electronic Control Units (ECUs) of the vehicle play a fundamental role. Then, I used systems modeling tools such as Domain Mapping Matrix (DMM) and Design Structure Matrix (DSM) to understand and quantify the patterns of interaction among vehicle features that occur across all Electronic Component Units (ECUs) of an automobile. Finally I developed a holistic proposal to adapt the strategy, methods, tools and organizational structure that is meant to support Ford Motor Company in its pursuit to disrupt the mobility paradigm.

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Dedicated to...

María Fernanda, thanks for your love and patience...we are the best!

My mom Aurora for her love and great life witness....you are incredible!

My dad Guillermo† for his love and great life witness...you are always on my mind!

Alejandro & Ricardo for their support and love....you are my gang!

My nephew Esteban...I love your sense of wonder!

My new family, Guille, Homer, Gaby, Paty and Lulú for being part of my life.

Acknowledgements

I would like to express my gratitude to my thesis advisor Pat Hale. He was always willing to help me during this work and provided the guidance and advises to complete this thesis.

I also would like to thank Asaad Makki for his great support to my career development within Ford Motor Company. His guidance and advice have helped me to seize this great opportunity at the maximum level.

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I. CHAPTER 1: INTRODUCTION

Enhancing the practice of Product Development has been addressed in multiple studies and published in all kind of documents ranging from theses and consultancy studies to papers in specialized journals. Regardless these works focus on the processes, tools, methods or the structure of organizations they all exhibit a common characteristic; a *reactive –"gap-filling"—* approach. They are crafted to *react* to new demands or challenges created by alterations or disruption around the practice of the business where these alterations may involve the need to develop new products for a new niche, or the need to reduce costs or cycle times, the entrance to a different market, arrival of new competitors, etc.

While this *"gap-filling"* approach has provided good results for those who do it fast, it's also true that the information used in the creation of such solutions, comes from the *past*. Consequently the determination that an improvement is necessary occurs by analyzing past evidence which ultimately reveals the gaps that need to be fixed—conventionally tagged as "areas of opportunity". This *reactive adaptation* responds to the typical scalable efficiency paradigm which assumes some stability in the business environment and as a result the attention is focused only on enhancing methods, processes, tools while just scaling the hierarchical organizational structures accordingly. [Chansanchai (2015), Gromball (2015)]

The main contribution of this thesis is the proposition that enhancing the practice of product development is better achieved when it is addressed from a holistic perspective in which either the improvement, optimization or enhancement of the product development practice is in essence an adaptation of the product development organization. Seeing it from the *adaptability lens,* allows us to create enhancements that go beyond the traditional *"gap-filling"* approach of fixing issues using information from the past, and opens up a broader –yet richer—set of alternatives to design solutions that not only prevent issues to occur but that also can *change the game* .

This work presents the development of a *disruptive-adaptation* proposal for a product development organization that wants to compete in the digital era by not only improving their core businesses but also seizing emerging opportunities. This proposal focuses in the realignment of resources and the evolution of engineering strategies to excel in the development of new products. It pretends to model the actions expected from strategic managers in product development that seek to contribute to the success of the company's business strategy.

1.1 Motivation

The Digital Transformation, as previously other technology evolutions did, is overturning the way how businesses are being done. Nevertheless, what is unique to this disruption is that it comes characterized by a strong risk taking culture that embraces failure, and see it as the opportunity to learn. This culture promotes to trying out new ways to do things leading us to observe amazing shifts in paradigms.

So, I think it is time to shift the paradigm of adaptability, and work on a new type of adaptation, one that instead of reacting changes in the environment, it is meant to change environment.

In this work, I want to apply a *systems thinking* approach to explore an "*in advance*" adaptation re-design for a product development organization that is re-inventing its business models in order to seize the emerging opportunities that will be brought by the digital transformation, in which we are already immersed.

1.2 Objective

Design a *disruptive-adaptation* proposal for the redesign of the **capabilities for the development of "in-vehicle" features,** of the Product Development Organization of Ford Motor Company. This proposal is focused on appropriate enhancements in structure and strategy that should be adopted in order to deliver future products to disrupt .

1.3 Research Method

This thesis followed the deductive research approach for the development of a theory. Since the expected result was a *disruptive-adaptation proposal*, certainly it fits within the concept of a theory, in the sense that it represents a proposition that has not been proved. Specifically, for the adaptability proposal, it's suggested as management strategy.

I started with formulating assumptions about the products that Ford Motor Company will develop in the future as part of its plan to disrupt the way the world moves.. These assumptions were built with information researched in technology reviews and publications about future trends. Also, I listed the business strategies pursued by the company. Later, I conducted a case study about the current capabilities in the development of *in-vehicle features*, where I collected data about the execution of one project that is about to be launched.

With this information I carried out an analysis of the engineering processes and strategies that are currently followed by the Ford's Product Development Organization for the design and development of *in-vehicle features* as well as the organizational structure in place. I used all this information to derive an adaptability proposal that is meant to be in alignment to the business strategy of Ford Motor Company.

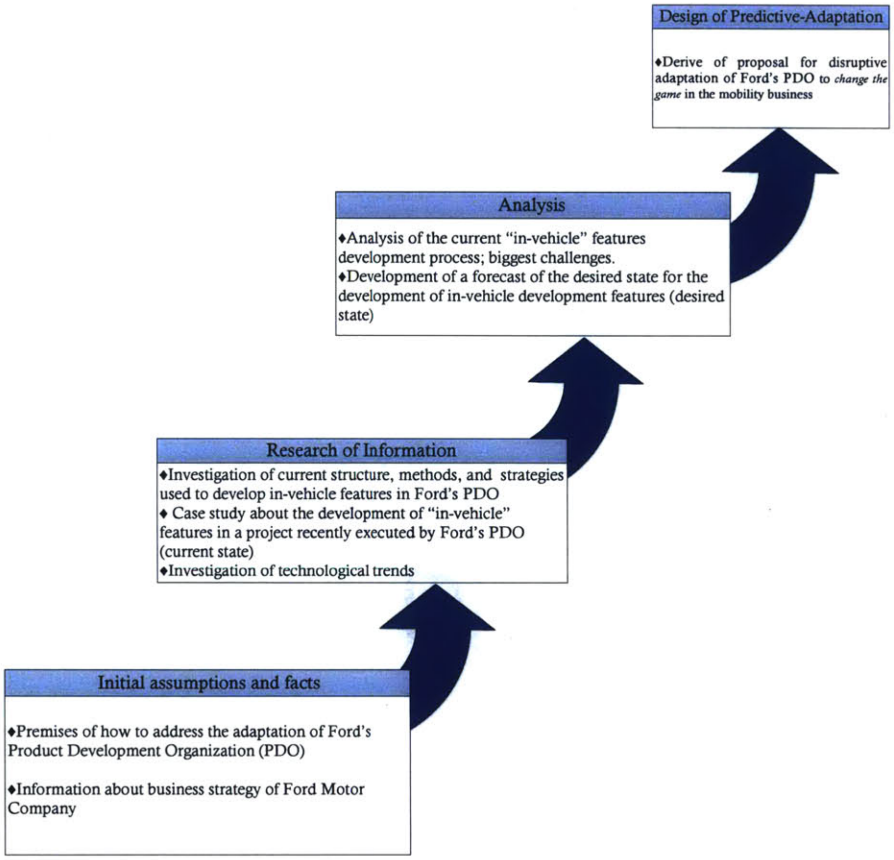


Figure #1*. Research method overview*

1.4 Thesis Structure

After the introduction, Chapter 2 presents information researched on literature relevant to the topic addressed in this thesis. This information includes a review of the key concepts like "adaptability", the generic view of product development processes and organizations within the automotive industry, and the description of the practice of model-based systems engineering. Also, it presents information on about the most recent frameworks for innovation. Finally it presents a summary entitled "engineering vision 2025", which seeks to describe the dynamics in the technology business that can be anticipated from technological trends and the creation of new business that has been addressed in multiple publications on new technology trends and management. The purpose of Chapter 2 is to communicate key insights on the aspects to be considered by technology firms looking to compete in the *digital era*.

Chapter 3 outlines a framework of the relevant terms and definitions about adaptability in organizations. The concepts described in this are used as baseline for the case study.

Chapter 4 presents the case study of Ford's product development organization, specifically in the capabilities currently used to develop "in-vehicle" features. It describes the different sources of information used to gather data and how this was analyzed to identify design inputs for the adaptability proposal. Moreover, it contains the design sequence that was used to craft the *disruptive adaptation*, and outlines how besides the design inputs derived from the data analysis, the proposal included key aspects that should be considered in to better align its execution to Ford Motor Company business strategy on emerging opportunities. Afterwards, the adaptability proposal is described in terms of form (organization design) and function (engineering methods).

Chapter 5 contains a discussion of the adaptability proposal. It highlights key enablers for adoption and points out the opportunities that were identified to achieve the evolution process. These opportunities focus on making the best utilization of the company's current structure in order to adapt faster. The end of this chapter lists the conclusions of this work and comment on recommendations for future work.

II. CHAPTER 2: LITERATURE REVIEW

2.1 Adaptability concepts

Depending on the context the term "Adaptability" might have slightly variations in its conception. As starting point I present a couple of definitions that I excerpted from two distinct frames of reference:

ESD terms and definitions volume [The ESD Symposium Committee (2007)]

"The property of a system that can change its structure, processes and behavior to meet changing requirements in its environment; the changes under adaptability may be more complex than is available from flexibility"

In the context of mechanical design [Gu (2009)]

"The capability of an existing design to be adapted to create a new or modified design based on the changed requirements".

From these two definitions it is necessary to distinguish a difference between the property or capability and the process. From a *system thinking* perspective *adaptability* is an emergent property. The concept of *adaptation* refers to the action of adjusting to changes in the environment conditions, in which the individual, product, system or organization is immersed. Also, it is important to highlight that these definitions associate adaptability to adjusting due to a changing environment, that is to say, both definitions assume that the environment changed first and now it is the system or entity the one that adjust to that change.

2.2 Adaptability of Organizations

The adaptation of organizations is an extremely interesting topic, several many publications have been devoted to the analysis of how diverse corporations have gone thru the adaptation process and as usual the outcomes range from failure to success. During the literature review I was able to consult different sources and summarize the common concepts about the adaptability of organizations. In particular there were two references that I consider important to highlight:

- In his book *"Only the Paranoid Survive: How to exploit the crises points that challenge every company"* [Grove (2010)], Andy Grove describes his experience at Intel Corporation while he was Chief Executive Officer (CEO) and led the company through what he call an *"inflection point"*. According to Grove, an inflection point occurs when the business environment is disrupted dramatically causing the need for the company to re-invent itself in order to cope with new challenges and survive. Grove states that inflection points have always existed and they will continue to occur and highlights the main characteristics that an organization should possess or acquire in order to successfully adapt. He also emphasize the importance of being aware that inflection points will occur sooner or later and that is better to always be prepared to read and understand their signals.
- In "Adaptability: The art of winning in an age of uncertainty" [MacKeown (2012)], Max McKeown presents his research about the key principles of adaptation and provides multiple examples at many levels, from individuals to corporations and even civilizations. He presents baseline definitions for the steps to adapt (recognize, understand, do) and for the outcomes of adaptation (Collapsing, Surviving, Thriving and Transcending). With plenty of examples for each step of adaptation, where he compares the different outcomes of individuals and organizations, he describes the key characteristics needed to adapt successfully and also highlights the main barriers that have historically led both individuals and organizations to failure. One of his concepts that I found to be very interesting is his point about lessons from the past where individuals or organizations have reached the maximum outcome (transcending) by creating a whole new game. He points that as the ultimate level of adaptability.

Every process of adaptation is unique. Even organizations, doing the same business and facing the same challenges adapted differently. This is not only because the starting point—structure and operation of the organization—is different, but also because the end point of adaptation might vary. While some organizations just survive others transcend [MacKeown (2012)].

What follows is a list of the key takeaways that I learned during the literature review that I carried out about adaptability of organizations [Reeves, Deimler (2011); Mac Keown (2012); Grove (2015); Nussbaum (2007); Gromball (2015), Hacking HR to Build an Adaptability Advantage (2014)]:

- **When adapting, time is a very valuable asset**. If the aggregate time of the steps to complete the adaptation takes too long, the likelihood of failure increases. It is possible to read and understand the signs that reveal the need to adapt but if the decision to act delays this will result in failure to adapt.

- **Typically the bottle neck is at the stage of action**. Factors like bureaucratic heritage, cultural barriers to embrace change, discomfort with instability, and a large hierarchy can contribute to slow the modifications and execution of adjustments.

- **Former success may be your obstacle to implementing changes.** When a person in the organization has achieved success in the past, sometimes they tend to keep things as they were. When modifications needed involve re-shaping former practices or methods or even getting rid of them to bring new ones, these people focus on adjusting by using the old practices. They lock into what they call "best practices" and end up impeding a successful adaptation.

- **Imagination & creativity to spur forward thinking.** In order to create a larger number of possible actions for a solution—then increasing the possibilities to succed in the adaptation—organizations can promote looking at the challenges from different perspectives and not only within the conventional ways of how things are done. Embracing diversity can help on generating fresh ideas. Listening to people outside the organization that also pursue the same or similar interests also helps in expanding the horizon. A good example is what Microsoft is doing with its "Future

Visions" project in which they invite today's greatest science fiction authors to use leading-edge work developed at Microsoft's research labs, in order to craft compelling science fiction stories about what this technologies might bring in the future as science fact.

- **Rapid experimentation for fast learning.** Forecasts are not created by traveling to the future and reporting what was seen there. With high levels of uncertainty, forecasts might help to prepare alternatives and strategies; however, fear to failure may inhibit the organization to try new things out. Learning from experimentation allows the organization to determine the right course or confirm whether the modifications really conduct to the targeted course. Learning rapidly enables the organization to act on time, avoiding realizing the needed actions late.

2.3 Scenario Planning

In an attempt to avoid being surprised by difficult scenarios in the future derived from dramatic and unexpected changes in business environments, the strategy and planning teams in many companies apply "scenario planning" techniques that are meant to develop possible futures in order to plan according to this situations. The main idea is to being capable of imagining the worst case scenarios that could compromise the operation of organizations, and from develop contention strategies that will allow the company to overcome such difficult conditions in case they present. Pierre Wack is considered to be the father of this method and during the time he worked for the Shell's Group Planning department "he alerted Shell's managing directors in advance about some of the most confounding events of their times: the 1973 energy crisis, the more severe price shock of 1979, the collapse of the oil market in 1986, the fall of the Soviet Union, the rise of Muslim radicalism, and the increasing pressure on companies to address environmental and social problems" [Kleiner (2013)].

The key takeaway about scenario planning is that focuses in anticipating future changes that cannot be controlled by the organization. Instead is about predicting the possible changes that the business environment could bring in the future.

2.4 Overview of Product Development Process in the Automotive Industry

A Product Development Process (PDP) is the sequence of steps or activities that an enterprise employs to conceive, design, and commercialize a product [Ulrich, Eppinger (2016)]. In the case of highly complex products such as an automobile, its development is achieved with the participation of multidisciplinary teams through different stages. Figure #2 shows a representation of the key stages during the development of a vehicle.

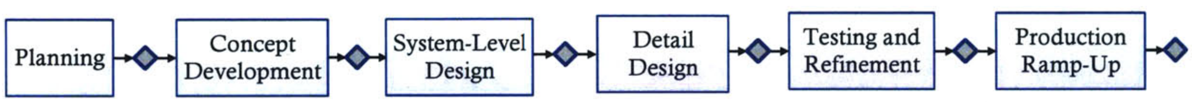


***Figure #2**. Generic Product Development Process*
(reproduced from Ulrich and Eppinger, (2016), p-12)

In order to deal with the complexity, the development is conducted following the Systems Engineering (SE) interdisciplinary approach which "focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with the design synthesis and system validation while considering the complete problem: operations, cost and schedule, performance, training and support, test, manufacturing, and disposal. SE considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs" [INCOSE Systems Engineering Handbook v. 3.2.2, p-6].

A central strategy of SE is the decomposition by which the entire automobile –the top level system—is partitioned in order to obtain smaller subsystems with reduced complexity. The decomposition proceeds successively until eventually reaching the component level which is the minimum unit of partition. The plane –or criterion— of decomposition is determined from a holistic assessment that certainly is highly influenced by the delivered function and physical domain but also considers aspects of manufacturing, assembly, ergonomics, and maintainability among others. Requirements for the interactions and interfaces at the component and subsystems levels play a fundamental role to enable a cohesive integration of the top level system

The Vee model (Figure #3) is a graphical representation of the systems engineering approach.

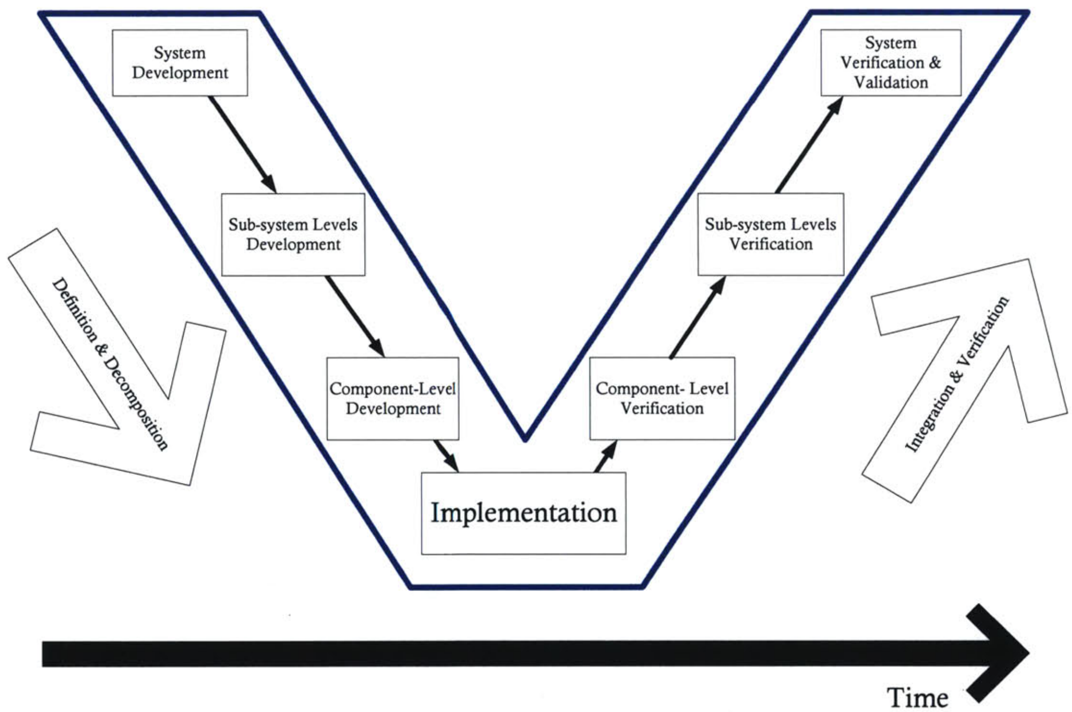


Figure #3. *Vee model for systems engineering (adapted from INCOSE Systems Engineering Handbook v. 3.2.2)*

The left side of the *Vee* depicts the decomposition process which starts at the top level system. At this point, the customer wants and needs are listed and the *design intent* is conceived. As decomposition progresses, it drives the creation of the requirements that define the functionalities expected at each subsystem level down to the component level, and that are used to develop the detailed design of sub-systems and components as well as to build the verification and validation plans.

The right side of the Vee shows the bottom up integration from component level to top level system. The design verification occurs at each level to demonstrate that the functions are met *–building the right product.* Also, validation of all components and subsystems is conducted towards production ramp up phases in order to ensure assembly and manufacturing quality *–building the product right.* As the capabilities for computer aided engineering have increased this has resulted in the integration of virtual verification phases during the stages at the left side of the Vee model.

For its design and development, the automobile is typically decomposed in 6 main subsystems; Chassis, Body Exterior, Body Interior, Powertrain, Electrical, and Climate (Heating, Venting and Cooling) as shown in Figure #4.

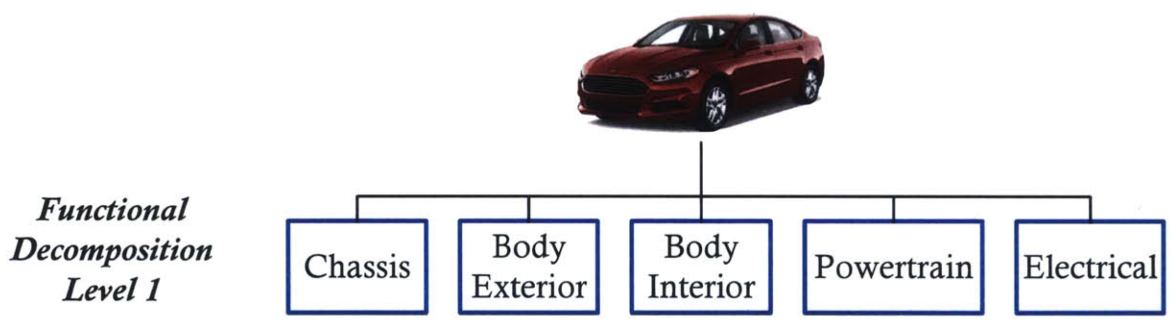


Figure #4. *Conventional functional decomposition of an automobile*

At this level the initial requirements capture the top level characteristics that are expected from the system. During the decomposition, the creation of requirements continues to define the operation and way of interactions at each level. At the end of the decomposition the majority of the components end up interacting with components from other subsystems and these interactions might be of the following types:

♦ Physical contact due to assembly purposes

♦ Information exchange

♦ Energy transfer

♦ Material Exchange

In the one hand, managing such massive number of interactions among all components demands a very precise definition of requirements which must be complete, consistent, accurate, and correct in order to ensure a robust system integration and clean execution during the product development. In the other hand, the traceability of requirements becomes critical as the components inherit requirements that were derived from subsystems at upper levels. Even with the best designed components, any failure in the definition of interactions and interfacing requirements will result not only in a product with reduced quality but also may impact heavily the cost of a project due to corrective iterations. Figure #5 shows the relative cost of correcting an error depending on the stage at which the error is discovered.

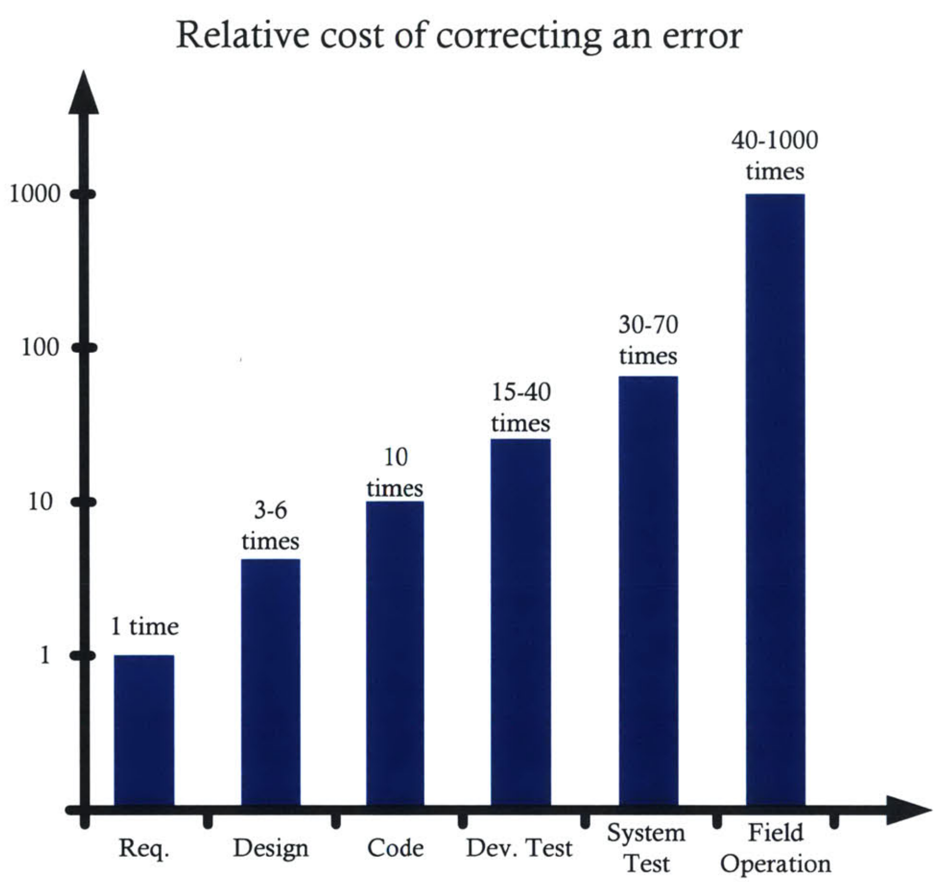


Figure #5*. Relative cost of correcting an error*
Source: Professor Pat Hale, Lecture on Systems Engineering at MIT, summer 2009

2.5 Model-Based Systems Engineering

The introduction of software for Computer Aided Engineering (CAE) enabled the virtual verification of components and even some subsystems at the mechanical, thermal, and electromagnetic domains before the construction of prototypes. In the case of the design of embedded systems, Model-Based Design (MBD) methods and tools were developed in order to support the early verification of components performance.

Although the implementation of MBD & CAE disciplines significantly improved the developmental costs and times, the verification of many requirements and operational scenarios at the higher subsystem levels continued to happen with prototypes.

The main reason is that—at some level of decomposition—in order to model the entire subsystem it's necessary the utilization of a modeling language capable to capture all those relationships that cannot be expressed with mathematical formulations as occur with the design of control algorithms for embedded systems, and components at the mechanical, thermal, electromagnetic domains.

Thus, in order to perform virtual verification of the system's *design intent* it was necessary the incorporate powerful modeling languages capable to precisely describe:

♦ Structure & hierarchy of systems

♦ Interactions

♦ Event sequences

♦ Behavioral aspects of the system

♦ Relationships among all above entities

There exist various languages for systems modeling like AP233, OPM and SysML™ (System Model Language), being the latter the most popular. It was developed by the Object Management Group [Unified Modeling Language, Object Management Group], and is an extension of UML (unified model language) that is used to model software. One of its advantages is that allows the modeling of systems with graphical representations of all entities. With the premise that "*the best way not to have defects in the system is not to put them* *there in the first place"* (Law of Douglass 71) [Douglass (2013)], software tools that incorporate SysML™, are to be used for the execution of system requirements models for the early verification of the design intent before the decomposition process continues to lower levels, avoiding the cascading of defective, inconsistent, conflicting, incorrect or incomplete requirements.

MBSE enhances the practice of systems engineering because it [Dori (2014)]:

♦ **Improves stakeholder communications** allowing team members from different disciplines to discuss the design intent with a unified terminology

♦ **Reduce ambiguity** that accompanies the text-based development of requirements

♦ **Reduce number and severity of errors** by enabling the early verification of requirements models which allows a more powerful way to identify gaps and errors.

♦ **Captures and represents organizational and system knowledge.**

♦ **Simplifies the Integration of Systems of Systems**, those systems that were not meant to interact on purpose but that have become interconnected as they have evolved.

2.6 Overview of Product Development Organizations in the Automotive Industry

The literature generalizes the design of a Product Development Organization (PDO) with the four archetypes shown in Figure #6.

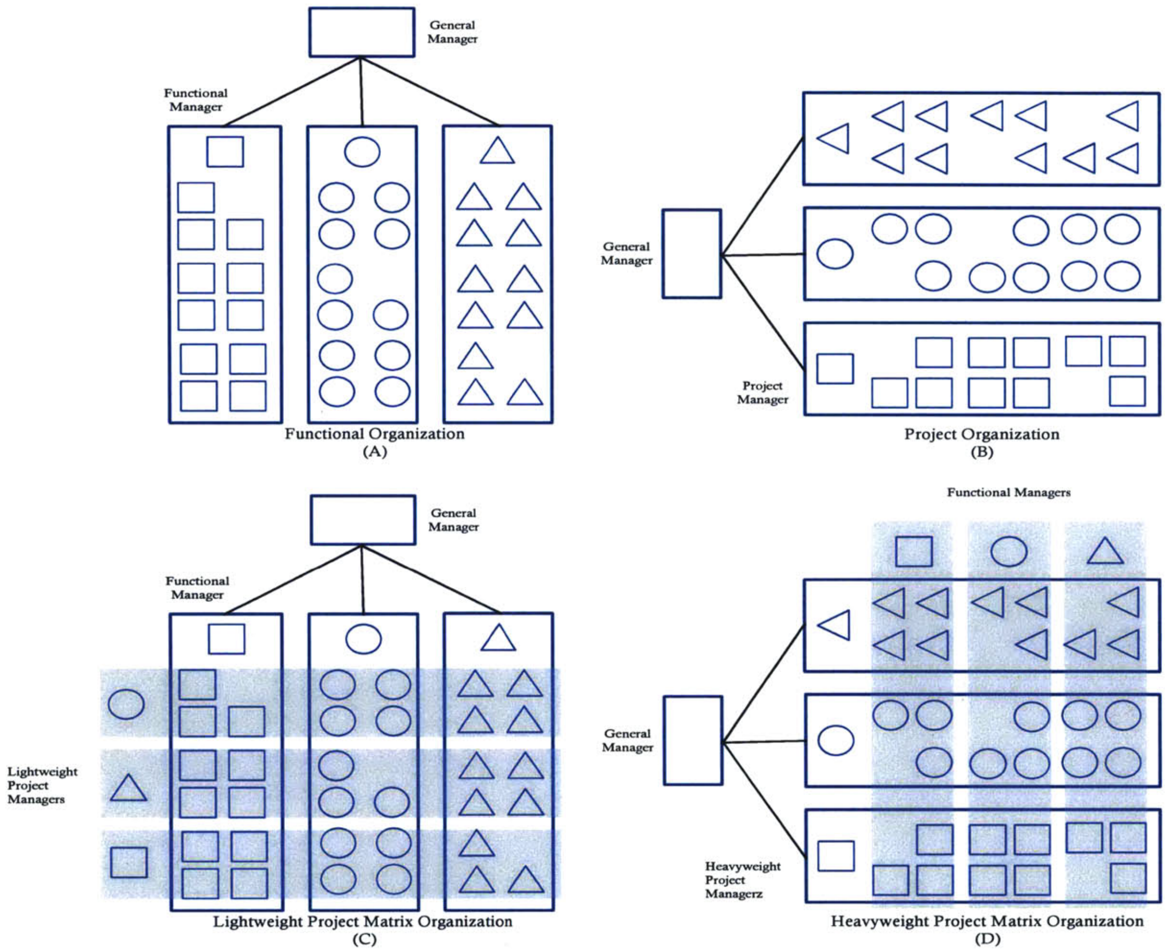


Figure #6. Four generic archetypes of product development organizations (reproduced from Ulrich and Eppinger, (2016) Product Design and Development p-27)

In the **Functional Organization (A)** design, staff is clustered according to the different specialties of knowledge, e.g. manufacturing, design, marketing, purchasing, etc. Team members share a common area of expertise and deep level of expertise on the functional area is developed. The work cells are led by functional managers to whom the team members report.

A **Project Organization (B)** design, groups the staff based on projects. The project teams integrate members with different fields of knowledge that work together in the development of specific projects and report to the project manager.

Additionally, here are two hybrid designs known as **Matrix Organizations** that result from the combination of the functional and project designs.

In the **Lightweight Project Matrix Organization (C)** the functional teams also belong to project-specific teams. Team members report to both the functional and the project managers but it is the earlier has the control on the performance evaluation and career development. The PD organizations in the automotive industry use this design.

The **Heavyweight Project Matrix Organization (D)** has the same format than the lightweight but in this one the project manager has complete authority over the project team members. The functional managers focus on providing guidance on the technical aspects given that they are responsible of the knowledge administration within the firm.

These four archetypes provide a good reference in the understanding of PD organizational design, and this provides information on the schemes for collaboration among the team members but the reality is that every organization is unique. They are shaped by the influence of diverse elements such company's strategy, business model, own processes, administrative heritage, and the type of products or services it delivers, among other factors [Simons (2005)].

Particularly in the automotive industry there is a strong bond between the system decomposition and the organizational design. The staff is clustered in alignment to the structure of the system decomposition of the automobile [Gulati & Eppinger, (1996)], and the organizational layers pretty much match the decomposition levels. Figure #7 shows a glimpse of the organizational design in an automotive product development organization. It highlights the route from the PDO general manager to the product engineer responsible of the design and release of the climate control unit (component) to illustrate the different organizational layers and how they are partitioned in clear resemblance of the automobile system decomposition.

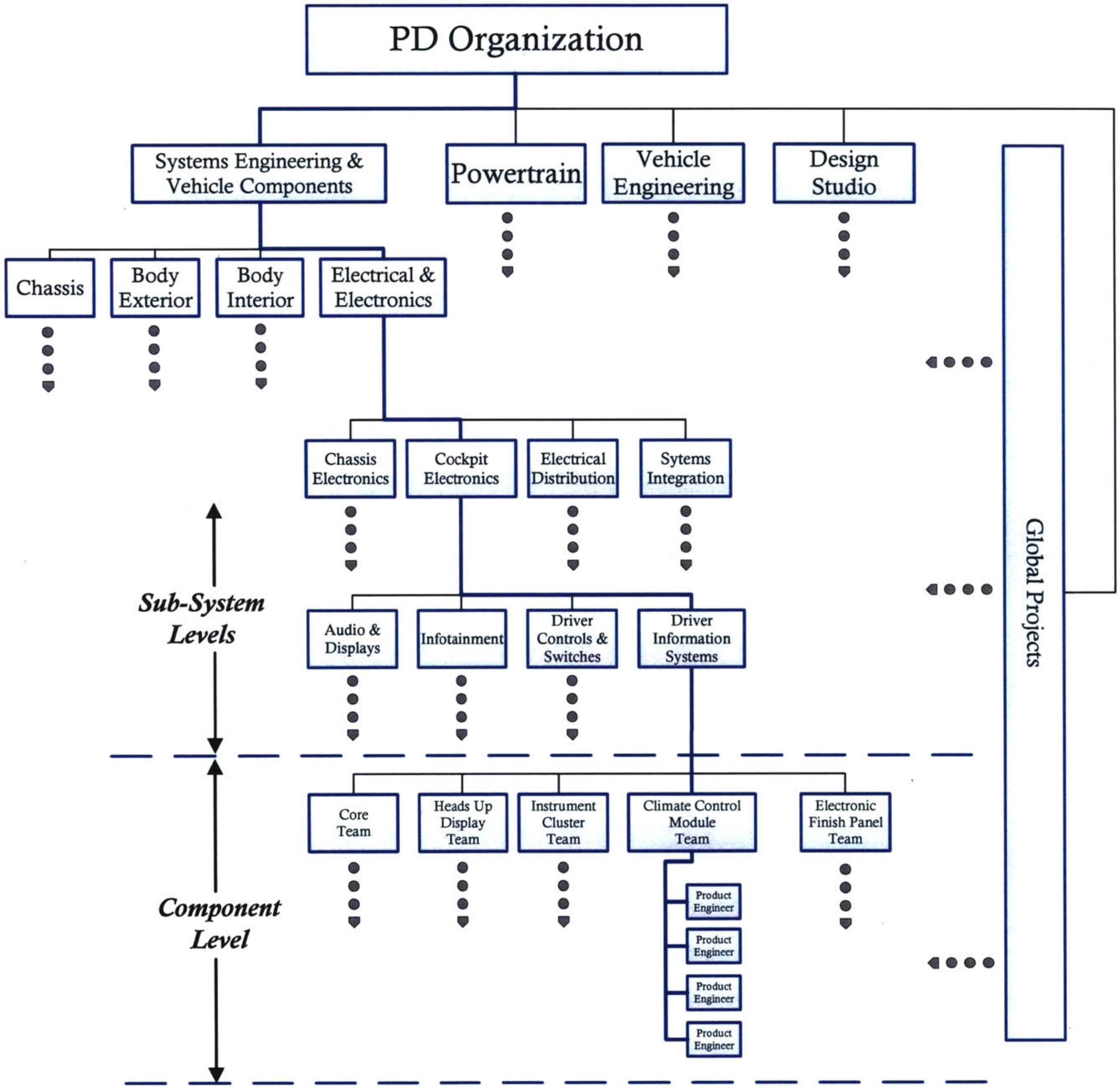


Figure #7. Glimpse of the typical product development organization chart in the automotive industry

This is a very important aspect to be kept in mind, because the implications of the alignment between system decomposition and organizational design have an impact beyond the automaker company itself. It has also shaped the structure of all the different companies that supply components to the automakers. Being vast majority of suppliers B2B companies, the architecture of the components they produce is derived from the system partitioning that was defined by the automakers. And the developmental collaboration of suppliers with automakers during the product development process is tailored to automakers organizational design.

2.7 Innovation paradigms

In this section, I provide a summary of the main innovation paradigms that have been utilized in the industry. They are presented in a synthetic way that will make clearer its differentiation and compatibility with the adaptation proposal subject of this work. Given the scope of this thesis, I do not provide full detail of them as the intention is only to provide the key concept of each paradigm.

TRIZ

TRIZ stands for "theory of the resolution of invention-related tasks". It centers in clearly defining the specific problem to be solved. Essentially, the innovation that is sought should be expressed as a problem that needs to be solved. From the specific problem the next step is to identify the technical contradictions that are present. The contradictions are mapped to the 40 inventive principles, which provide 76 standard solutions for the contradictions. Once the generic solutions are identified they are translated into the specific domain in order to create the specific solutions. Figure #8 shows a diagram of the TRIZ paradigm.

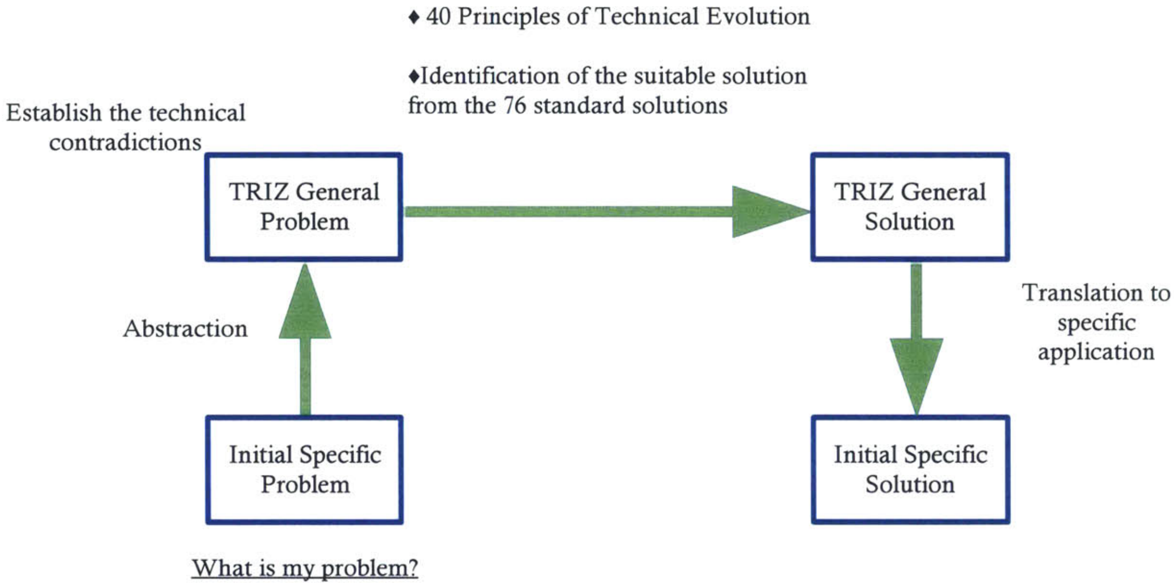


Figure #8. TRIZ paradigm for invention-related problem solving

This paradigm has been widely used in the industry, but even in cases where the explicit TRIZ methods are not utilized, what is common in the industry is the *company-centric* approach to innovate by looking at this activity as a problem-solving discipline.

User-centered Innovation

In explaining user-centered innovation paradigm, Eric von Hippel [Thomke, Von Hippel (2002)] proposes that looking at the solutions created by led-users, companies can continuously innovate the product by building on users' findings in a collaborative evaluation, replication and improvement of such solutions which are the result of a full understanding of product possible usages and limitations [Thomke, Von Hippel (2002)]. The main proposition that a company values from this paradigm is that the "voice of the customer" is heard directly and without biases. Moreover, lead-users are more likely to bring proposals and ideas "out of the box" as part of their involvement in both the development process and the day-to-day utilization of the product. In this innovation paradigm, the product development organizations deliver interfaces and tools that allow the led-users to design and create prototypes for evaluations and tests. Also they collaborate continuously with led-users in order to ensure that proposals and designs are feasible and producible. Besides the generation of outstanding ideas, companies benefit from a significant reduction in the design iterations. Figure #9 shows a comparison between the conventional paradigm to develop new products and the user-centered innovation paradigm.

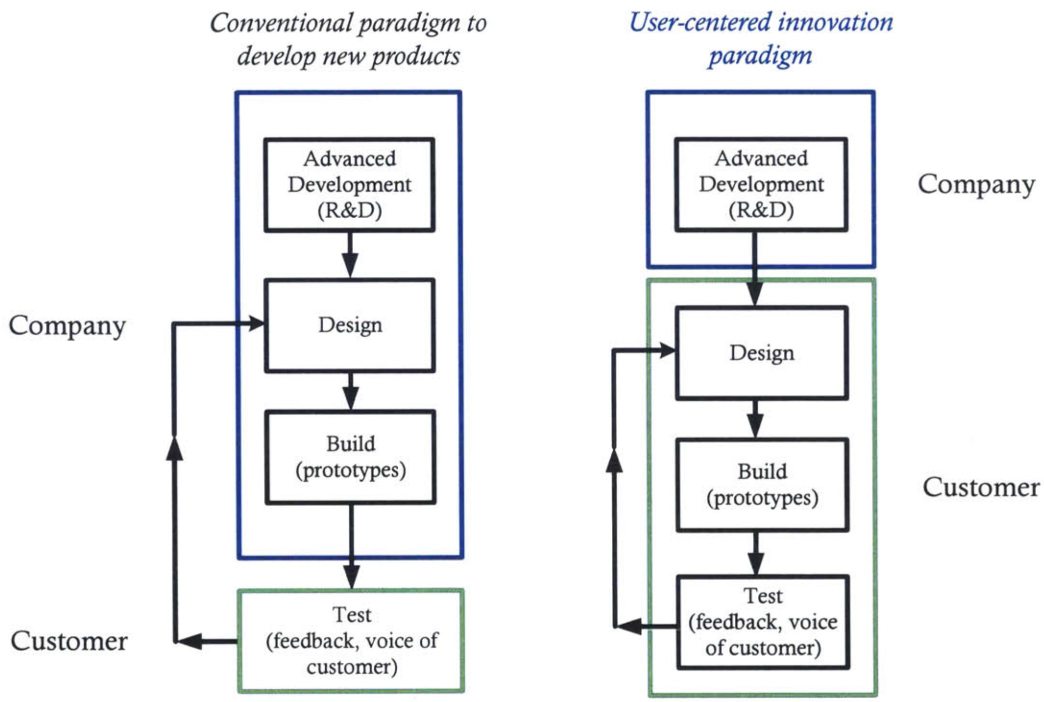


Figure #9. Comparison between user-centered innovation and conventional development of new products paradigms (modified from Stefan Thomke and Eric von Hippel 2002 [Thomke, Von Hippel (2002)])

Design Thinking

Introduced by Tim Brown, the founder of the consultancy firm IDEO, the design thinking paradigm for innovation focuses in the customer experience. It is by the full understanding of customer needs and experience that key insights are gained and are used to drive the ideation of proposals. In this paradigm, experimentation is crucial since iterating the proposals provides the refinement needed to create provocative products that connect with the customer. But in contrast to the conventional conception of exploration in the product development firms, what design thinking proposes is that the experimentation should be focused on exploring the experience of the user with the product in all contexts. The 3 main stages of the design thinking paradigm are:

♦ **<u>Inspiration</u>** – This is when deep observation of customer happens in order to understand what he struggles with, or even interim solutions that they have come with to fulfil their own needs.

♦ **<u>Ideation</u>** – In this stage the generation of alternatives occurs by multiple methods like brainstorming, but includes all sort of prototyping techniques. Ultimately this is about prototyping rapidly to evaluate proposals and continue gaining insights.

♦ **<u>Implementation</u>** – Once prototypes have shaped the final concept is when the serious step towards production occurs, in this stage, support is provided to marketing areas in order to communicate the design effectively.

In all stages there is a constant focus in the customer experience and this is why this widely followed not only in the innovation of products but also in the invention of services. In the end, the primary objective of design thinking is to connect with the user by providing a superior experience that can come from a product or from a service.

2.8 Engineering vision 2025

The *digital era* is one of the terms coined to refer to the transformation that is happening by the integration of digital technologies such as *social*, *mobile, analytics* and *cloud*. It's considered a big transformation because it is driving a fundamental change in the way how businesses are done. It not only drives new business models, but entirely modifies the way how they are executed.

A clear example of how Ford Motor Company is being digitally transformed is expressed in its –recently announced—strategy which considers to strength its core business – designing, developing, manufacturing, and building great cars, trucks, and SUVs- while seizing emerging opportunities focused in the customer experience. In this new strategy, FMC defines itself as a mobility company, which implies not being limited only to manufacture vehicles for transportation in the conventional ways but expanding its vision to the entire set of options to enhance people's mobility, which includes autonomous vehicles and development of products and services to facilitate people's access to services that require some sort of transportation. In current paradigm the *people moves to things*, and in the scope of these emerging opportunities for mobility, what is intended is to explore how *things can be moved to people,* and smart combination of both.

In an exercise of pre-visualization of future scenarios, I carried out a research about technological trends and business models that could intertwine over the next years creating a business dynamics compatible with the "emerging opportunities" that Ford Motor Company would be interested to seize as part of its mobility business.

Starting from that forecast, I plan to identify the key capabilities that FMC product development organization might need to master in order to be capable to create the products and services needed to capitalize those "emerging opportunities" and become not only the undisputed winner but the *game-changer* company as occurred when it disrupted the automotive business with the introduction of the moving assembly line.

As result of this analysis, I identified the following technological trends that I consider will become key enablers to produce new products for mobility

Software Development.

The digital transformation started with the implementation of software systems to run multiple processes from credit card transactions to the management of employee's data. Today, software is everywhere, running automobiles, powering internet applications to provide video streaming services, and in consumer electronics products of all kind. Software is the backbone of nearly all applications of daily use, and will continue driving the digital transformation of business. Then it will be necessary that every company to become software company in essence [Andreesen (2011), Porter & Heppelman (2015)].

Sensor technologies

Current production low costs of a –always increasing—variety of sensors, combined with its increased miniaturization, low power consumption rates, and wireless communication capabilities are the main conditions that allow its rapid spread in practically every environment. It is expected, they are to be present in almost everything; clothes, smartphones, watches, drones, public infrastructure, transportation systems, pets, et cetera.

Reliable and robust communication protocols that exist today will enable a massive collection of data to track and measure almost every process.

Data Analytics

Massive amounts of data coming from infrastructure and devices everywhere, will allow companies to gain insights on the products they develop and the potential services that can be derived from them. Data containing comprehensive information of the environment in which a product is operating will allow –for instance—boosting the safety of transportation systems in order to reduce the number of accidents [Ransbotham (2015)].

Haptics & Virtual Reality

The development of haptic devices has increased significantly due to similar enablers for sensors development such as miniaturization of devices, wireless communication capability and reduced power consumptions. Today its main presence is in touch screens applications and in control devices such as steering wheels but an increased presence is expected in wearables and smart clothes, in which there will be a closed loop from sensing vital signals and environment conditions to providing haptic feedback. The combination of haptic devices with Virtual Reality technology is expected to boost the proliferation of *augmented reality* applications that will provide enhanced experiences in different environments that might also include transportation.

Robots & Automation

Robotic systems are present in all heavy industries. They perform high precision activities faster and in environments that are not secure for humans. However the robots have been spreading rapidly to other environments like health care, where robots are manipulated by physicians to perform high precision surgeries. The *consumer robotics* era [Consumer Robotics, Tractica (2016)] has taken off, with bots carrying and distributing material within hospitals or household robots for vacuum and lawn mowing. Robots are adopting human machine interfaces as they are becoming smarter to interact with people in varied environments so we can expect that in the short term consumer robots will populate homes and be present in public spaces like malls and parks. Other foreseen applications are identified in the assistance of older people as companions and servants given that worldwide, the number of people aged 60 and over will double by 2050 [Oppenheimer (2015)].

It will not be surprising seeing robots as extensions of autonomous cars to enhance mobility in crowded public spaces.

Drones and unmanned delivery

Delivery of goods of all kind is an activity that has been increasing consistently as the e-commerce grows. One option in mind to speed the delivery process and reduce costs is the use of unmanned drones. Nowadays what is perhaps its biggest limitation is the range they can travel with a single battery charge. It is expected that solutions to combine the actuation of autonomous cars and drones to emerge in order to cope with the limited range current drones provide. This combined actuation could provide the drones with mobile recharging stations and hubs to allocate merchandise to be delivered. The drone-to-vehicle collaboration might also create schemes where packages are finally delivered by an autonomous road vehicle (not necessarily an automobile) that receives the package from a drone which was useful to skip the traffic jam. Initial steps towards this future were kicked off by Ford Motor Company when announcing the "Drone to Vehicle Developer Challenge" in conjunction with DJI [2016 DJI Developer Challenge, DJI (2016)]

Internet of Things

The technology trend that connects all technology paths presented above is the Internet of Things (IoT). By leveraging cloud computing, the IoT proposes a highly complex ecosystem of connected devices sharing information and being acted remotely by centralized computing systems at the cloud. It's expected that once the interactions start, the different players will track how customers connect their devices and services in order to create new products and services. These will create the need of integrating strategies between different developers in the pursuit of seizing new market opportunities.

III. <u>CHAPTER 3: Disruptive Adaptability: Proposed Framework</u>

During the literature review, I was able to identify key terms and concepts that are needed in order to address the case study. What follows is the proposed framework that I suggest to address the case study. The definitions presented here are consolidated based on the literature review about adaptability and focused in the adaptability or organizations.

3.1 Stages of Adaptation

<u>Recognition</u>. The conscious comprehension that, conditions in the business environment have changed resulting in the need to adapt. It requires the ability to decode the signals in the business environment that reveal the changing conditions.

<u>Understanding</u>. That is the realization of what is needed to adapt. It involves setting the course.

<u>Action.</u> The final step is to implement the adjustments. This involves going the route of the *"how"*, and may involve iterations.

3.1 **<u>Levels of Adaptation</u>**

<u>Sufficient</u>. The implemented adjustments allow the organization to continue operating.

<u>Superior.</u> Actions in place enable the thriving of the organization which becomes strengthened in position and domain.

<u>Stunning.</u> This is when the organization emerges as the big leader, not only winning in its business sector but creating new business models.

3.2 Types of Adaptation

Reactive. Occurs when the recognition of adaptation takes place once the changes in the business environment are present and evident.

Predictive. It is created in advance by developing forward-thinking analysis.

3.3 Schemes of Adaptation

Merger. This is the case when two or maybe more organizations fuse to cope with the challenges ahead. The enrichment of core capabilities is achieved by combining each company's capabilities.

Acquisition. When the capabilities needed to adapt are obtained by acquiring another company that possess them.

Evolution. The capabilities of the company are taken to a new level. In this case, the original organizational resources remain but they are enhanced by the addition of new capabilities either by learning or by the integration of new resources.

3.4 Novel Concept –Disruptive Adaptability

The literature review revealed that adaptability is conceived as adjusting due to changes in the environment. Specifically in the adaptability of organizations this refers to the case where the business conditions change and the corporations need to adjust in order to cope with the new challenges. This is the first level of adaptability for which I'm using the term "reactive adaptation". Also, information was found about the case when organizations make use of forecasts to identify possible future changes in the environment and they prepare in advance to face them. Basically this is what I have stated in this framework as "predictive adaptation". In this second type of adaptability, the organization is better prepared to face the challenges but still this is about adjusting to changes in the environment.

Based on my research, there is still another type of adaptability. One that considers that the environment is going to be deliberately changed by the organization. In this third type of adaptability that I define here as "disruptive adaptability" the idea is that an organization determines the "*new game*" it wants to play. This is not adjusting because the environment changed or will change, instead, this is about adjusting to the new environment that organization is pursuing to create or modify.

To my knowledge, this type of adaptability has not been defined before. In my search of this concept I found that Gromball [Gromball (2015)] mentions the term 'disruptive adaptability', but in my understanding he points to the case of adapting according to dynamics brought by the digital era. Basically, in my opinion, he refers to provide organizations with the agility to seek and seize new opportunities open by the rapid changes in the business environment and that are consequence of the digital disruption.

I also found the term "disruptive adaptation", mentioned by Ehde [Ehde (2016)], but in his description I could identify that what he points as disruptive adaptation indeed corresponds to what I have framed here as predictive adaptation.

The reason of defining this term obeys to my understanding that in order to *change the game of mobility*, in the way that Ford Motor Company is intending, it is necessary another type of adaptation. One in which the adjustments in the organizations are meant to enable this change in the way how the world moves. Given that Ford Motor Company is pursuing such dramatic disruption in mobility, this is a case where this company is not preparing for the changes in the business environment but instead for changing the business environment.

IV. CHAPTER 4: CASE STUDY

In the past chapter I framed the concept of Adaptability of Organizations. This case study followed the deductive approach of the development of a theory in which I used the adaptability framework developed in Chapter 3 to design an adaptation proposal for the product development organization of Ford Motor Company.

4.1 Premises and Initial Facts

4.1.1 Premises

i. As revealed in the literature review, the successful adaptation of an organization is unique. It should be designed to firm's specific needs and based on its current state. Consequently it is necessary to understand the current state of the organization in regards to the aspects scoped in the design of the adaptation proposal.

ii. The development of this proposal is meant to be fully aligned to Ford Motor Company goal of changing the way the world moves [Ford at CES Announces Smart Mobility Plan and 25 Global Experiments Designed to Change the Way The World Moves", Ford Media Center (2015)].

iii. By addressing the adaptation of Ford Motor Company capabilities for the design of *in-vehicle features*, there is a directly impact on the development of the customer experience delivered by Ford vehicles which constitutes one of the key pillars in Ford business strategy.

4.1.2 Initial facts: Ford Motor Company Business Strategy

In its 2015 annual report, Ford Motor Company shared its vision for the future which is depicted in the diagram of Figure #10.

Figure #10 Ford's Business Strategy [Ford Motor Company 2015 Annual Report, page 31, (2016)]

This vision considers three main components for its strategy:

1. *Strengthening today's business* which is designing, developing, manufacturing, and building great cars and trucks, and SUVs.
2. *Pursuing Emerging Opportunities* in products and services for mobility.
3. *Customer Experience* as the key value for customers. [Ford Motor Company 2015 Annual Report (2016), p 31-32]

This update in the strategy reflects a change in which the company is switching its business model from product-based to platform-based. The value creation now goes beyond the benefit of the automobile but extends to services that will facilitate mobility while the value capture now expands to other options besides the purchased product.

But what is extremely exciting about this, is the intrinsic goal of *changing the game* in the mobility paradigm. Ford has proposed to use innovation not only to create advanced new vehicles but also to solve today's growing transportation challenges. At the 2015 Consumer Electronics Show Ford announced its ultimate purpose is to change the way the world moves just as its founder Henry Ford did 111 years ago [Ford at CES Announces Smart Mobility Plan and 25 Global Experiments Designed to Change the Way The World Move (2015)]. Basically Ford Motor Company has proposed to disrupt mobility.

4.2 Data Collection

From premise *i* that this thesis will focus on developing a particular solution, rather a generalization, the data collection centered in understanding the current state of Ford Product Development Organization in regards to how the customer experience is developed. Per premise *iii,* I started to analyze the current strategy for the development of *in-vehicle features.*

4.2.1 Customer Experience Development –Current State

Research Question:

How is the customer experience engineered?

As commented in Chapter 3, an effective strategy to design a complex product is by treating it as a system and decomposing it according to the most convenient criterion. The typical decomposition of a vehicle follows a hierarchical partitioning of functional sub-systems that ends at the component level.

Ford PDP follows the conventional sub-systems-to-components partitioning which at the bottom level encompasses physical components of all kind. However given the growth in the complexity of the automobile's functions, the concept of "feature" was incorporated to the design process for a better management of the complexity from the integration standpoint. Ford uses a "feature-based" plane of decomposition, to partition the amenities and functionalities that build the experience of vehicle's occupants. Ford's library of features contains 371 features but the specific number that a particular vehicle contains varies depending on the type of vehicle and the version. For instance, features like ***smart trailer tow*** **are only available for trucks and still only on high end versions.** This feature shows the driver which lights on a trailer connected to the truck aren't working so the driver or passenger doesn't have to get out of the truck and walk around the trailer.

Figure #11*. Human-Machine Interface of the Smart trailer tow feature*

Decomposing a vehicle into features, helps to identify the value creation in the development of the customer experience, however, while this is a convenient approach, it is also true that requires integration tasks between the different owners of the components that conjugate in the feature execution. Therefore, it is important to understand the strategy that is followed for the development of features.

This led me to the next research question:

How are in-vehicle features architected?

A very powerful strategy to understand the architecture of vehicle features without getting lost in the overflowing quantity of components that a vehicle has today is by centering the analysis in the Electronic Control Units (ECUs). This permits a holistic and nimble analysis of the feature development process, by using the *system thinking* approach for complex systems.

The ECUs are the mini-computers that read and process information from multiple sensors, execute the control logic, and command the actuators. In the example of the *smart trailer tow* feature, its execution requires the intervention of four ECUs that collaborate to read driver's inputs (menu selection at the human-machine-interface), assess information obtained from sensors, perform control logic and finally provide visual information on screen about the status of the trailer.

Thus, a very practical but substantial view of the integration of features is found by mapping how they are delivered through the ECUs. Figure #12 illustrates the strategic position of the ECUs within the delivery of vehicle features.

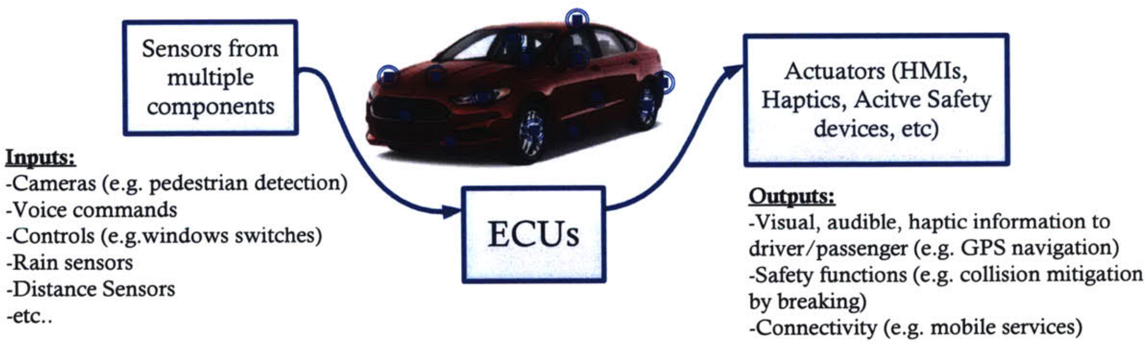


Figure #12. Diagram of the strategic position of ECUs in the value flow in the creation of the customer experience. They are in the middle of the sensors (inputs) and the actuators (outputs)

Connecting sensors with actuators places the ECUs as highly strategic elements from which to analyze the value flow in the creation of the customer experience because:

♦ They are at the bottom of the system decomposition followed in Ford's PDP which implies they are released as single components (also known as *end items*), and therefore produced by tier one suppliers. This allows the understanding of how the suppliers might impact the value creation process during the development of the component.

♦ Allows the identification of the product engineers that lead the design activity of each ECU and how they interact with their peers when the development of a feature involves the interaction of multiple ECUs.

For efficiency purpose I decided to concentrate the investigation in the design process of features in one ECU during the development of a new car line. The strategy behind this decision is to investigate how the development of features occurs from the perspective of the lead engineer responsible to release an ECU, which in turn receives the information of the features that his modules supports. With this, the obvious question was:

Which could be the right ECU to study in order to obtain the vital information about the current state in the design of in-vehicle features?

Identifying the right ECU to investigate

Analyzing large complex systems demands the ability to filter the right information in order to perform valid analysis in an efficient way. Similarly to the statistical sampling, in the art of *systems thinking* there is a variety of tools and strategies utilized to approach large complex systems to identify the vital few sources of data from which to obtain the substantial information.

In order to identify the right ECU to study, I started by building a Domain-Mapping Matrix (DMM) that relates features with ECUs. A DMM is a rectangular array that is used to visualize connections between elements of different domains. For example, a DMM can be used to show the team members assigned to the tasks of a project. Referring to the MDM in Figure #13, it is easy to understand that person "δ" is involved in tasks "e" and "f".

		Tasks					
		a	b	c	d	e	f
People	Person α	1	1				
	Person β		1		1		
	Person γ			1		1	
	Person δ					1	1

Figure #13. Example of Domain Mapping Matrix (modified from Professor Oliver de Weck lecture, on "Multi-Domain-Mapping (MDM) Matrices and Multi-Layer Networks at MIT, spring 2015)

MDMs are commonly used to model large complex systems given their powerful visualization capabilities that allow the identification of patterns and architectures from a holistic point of view. Thus, in order to understand how the features are distributed among the ECUs, I obtained from the company's product lifecycle management system a DMM that maps the 371 features contained in Ford's features dictionary with the 113 different ECUs that exist in Ford's product family. Consequently this "Features-to-ECUs" DMM is meant to provide top-level-view information about how the features are distributed across ECUs.

Figure #14 shows the "Features-to-ECUs" DMM whose size is 371 x 113. The coding of the matrix is as follows:

- Every cell stablishes a relationship between an ECU and a feature. If the ECU participates in the execution of the feature, the cell will contain a "1" in the opposite case it contains a "0".For visual aid, the cells are color coded to distinguish the "1s" from the "0s".

From the "Features-to-ECUs" matrix that subsequently will be referred as "FE" matrix, it can be identified those modules that participate in a great deal of vehicle features. While this information is useful to determine the direction towards which to focus the investigation of the *in-vehicle features* development, still additional data can be obtained from the FE matrix for which is necessary to introduce the concept of *Design Structure Matrix.*

A very powerful tool for modeling interactions occurring within large complex systems is the Design Structure Matrix (DSM). Also known as *"N^2 Diagram"* or *"Dependency Structure Matrix"*, DSMs are used to represent the following types of interactions:

Static Architecture. It shows the interdependencies existing in engineering systems, products and organizations.

Temporal Flow. It shows the progression of tasks or steps needed to happen for the completion of a project or a process.

Depending on the analysis that is conducted, the nature of the interdependencies expressed in *Static Architecture DSMs* can represent multiple aspects. For example, the DSM of a product can be used to map interactions occurring due to electrical connections among components (Figure #15) or could also map the number of shared functions performed by the sub-systems in which the product is decomposed (Figure #16).

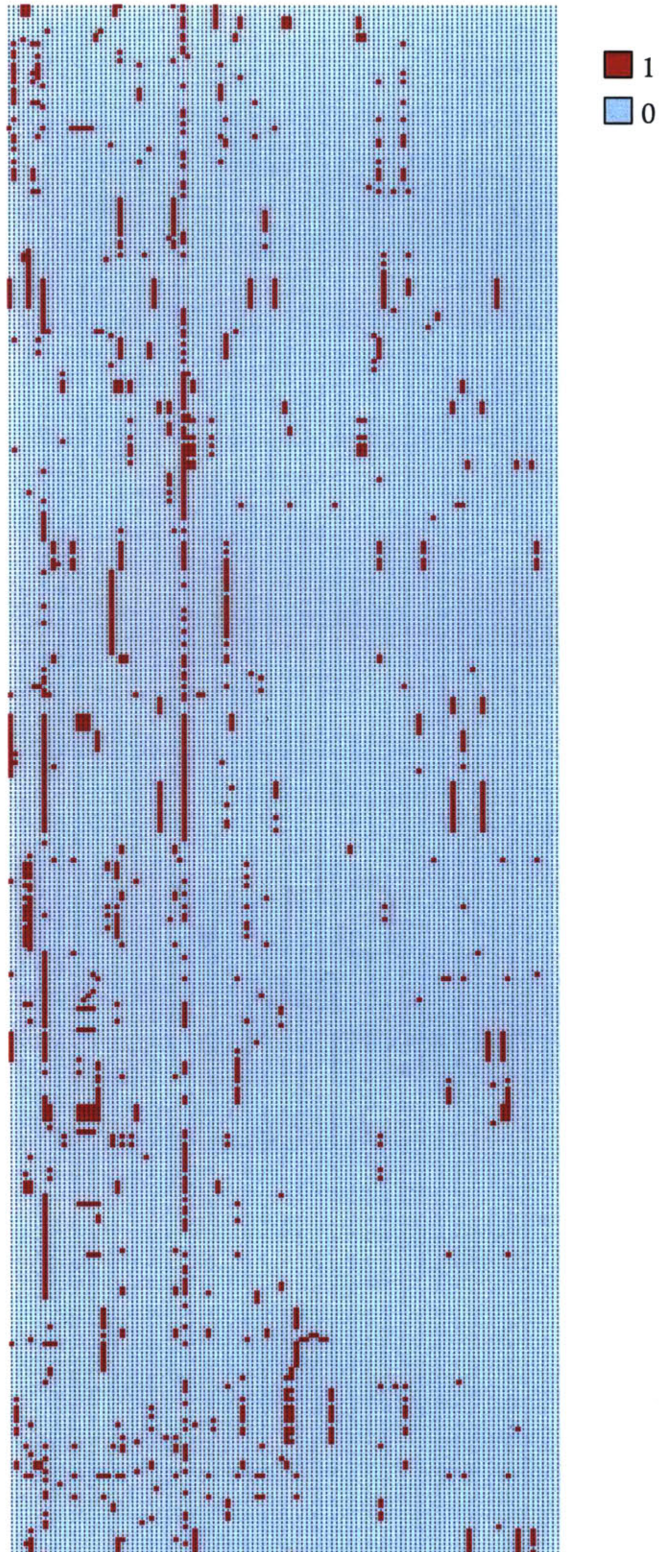


Figure #14 - "Features-to-ECUs" domain mapping matrix (371x113)

		A	B	C	D	E	F	G	H	I
Component 1	A		X							
Component 2	B	X			X					
Component 3	C									
Component 4	D		X							
Component 5	E						X		X	
Component 6	F					X				
Component 7	G									
Component 8	H					X				
Component 9	I									

Figure #15. Product DSM that maps the electrical connections among its 9 components

		A	B	C	D	E
Sub-system 1	A	**5**	1	0	2	2
Sub-system 2	B	1	**4**	0	1	2
Sub-system 3	C	0	0	**2**	1	1
Sub-system 4	D	2	1	1	**5**	1
Sub-system 5	E	2	1	1	1	**6**

Figure #16. Product DSM that maps the number functions that every sub-system performs in conjunction with other sub-systems

The DSM of Figure #16 shows the shared functions among sub-system, in the case of the sub-system "5", it is observed that it participates in 2 functions with sub-system "1" and in one function with the rest of the sub-systems. In the case of the cells at the main diagonal, the number corresponds to the total amount of functions supported by that particular sub-system.

There are plenty of options for attributes that can be represented with DSMs; in the analysis of organization architectures the interdependencies that are mapped can represent the frequency of meetings, hierarchy, or the number team members participating in common projects.

There exist a mathematical relationship between DMMs and DSMs. It is possible to compute a DSM from a DMM and with this to calculate the number of interactions among the elements of each domain. As the DMM contains two domains, then two DSMs can be derived from that DMM, one for the elements of each domain.

This can be directly obtained by squaring the DMM according to the following equations:

$$DSM_{m\,x\,m} = (DMM)_{m\,x\,n} \times [(DMM)_{m\,x\,n}]^T$$

$$DSM_{n\,x\,n} = [(DMM)_{m\,x\,n}]^T \times (DMM)_{m\,x\,n}$$

When applying above expressions to the **FE** matrix, the following information is derived:

$$Features\_DSM_{371\,x\,371} = (FE)_{371\,x\,113} \times [(FE)_{371\,x\,113}]^T$$

$$ECUs\_DSM_{113\,x\,113} = [(FE)_{371\,x\,113}]^T \times (FE)_{371\,x\,113}$$

By calculating the *ECUs_DSM*, the intention is to conduct a quantitative analysis aiming to identify the key ECUs suitable for further study. Figure #17 shows the "zoomed-out" view of the *ECUs_DSM.* The cells in the main diagonal indicate the total numbers of features that each ECU supports. The rest of cells in the matrix, show the number of features that each ECU shares with other ECUs. In order to determine those "key ECUs" suitable for further study, it is necessary to consider both criteria; on the one hand those ECUs supporting the largest number of features and on the other hand those ECUs with the largest number of shared features (interactions). In order to identify those "dominant ECUs" with more clarity, I applied Thebeau clustering algorithm [Thebeau (2001)] with which I could re-arrange the DSM in a format that isolates the groups of ECUs with highest degrees of connectivity. The clustered *ECUs_DSM* is shown in Figure #18.

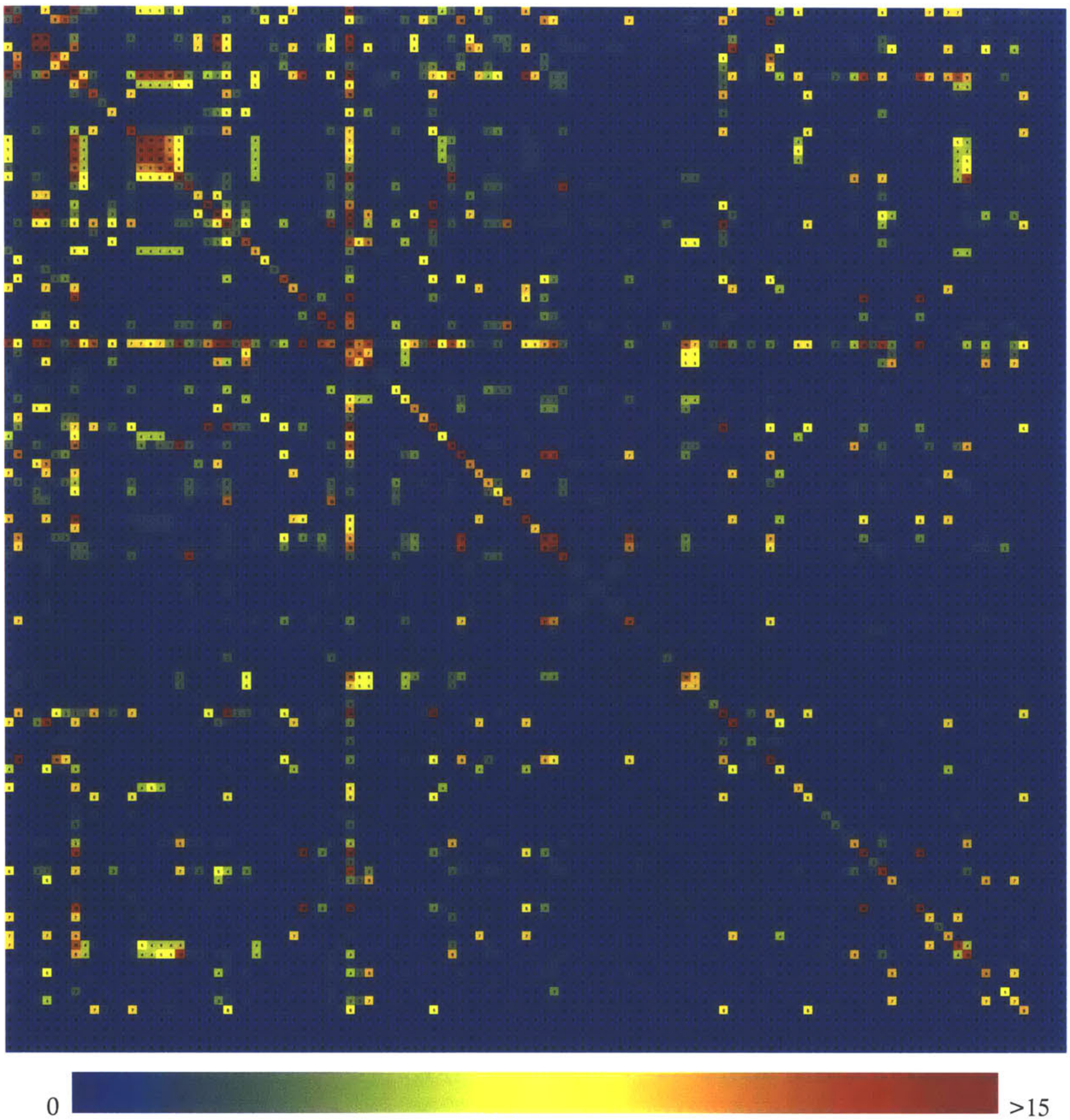


Figure #17. *"Zoomed-out" view of the ECUs_DSM. Data is depicted in heatmap scale.*

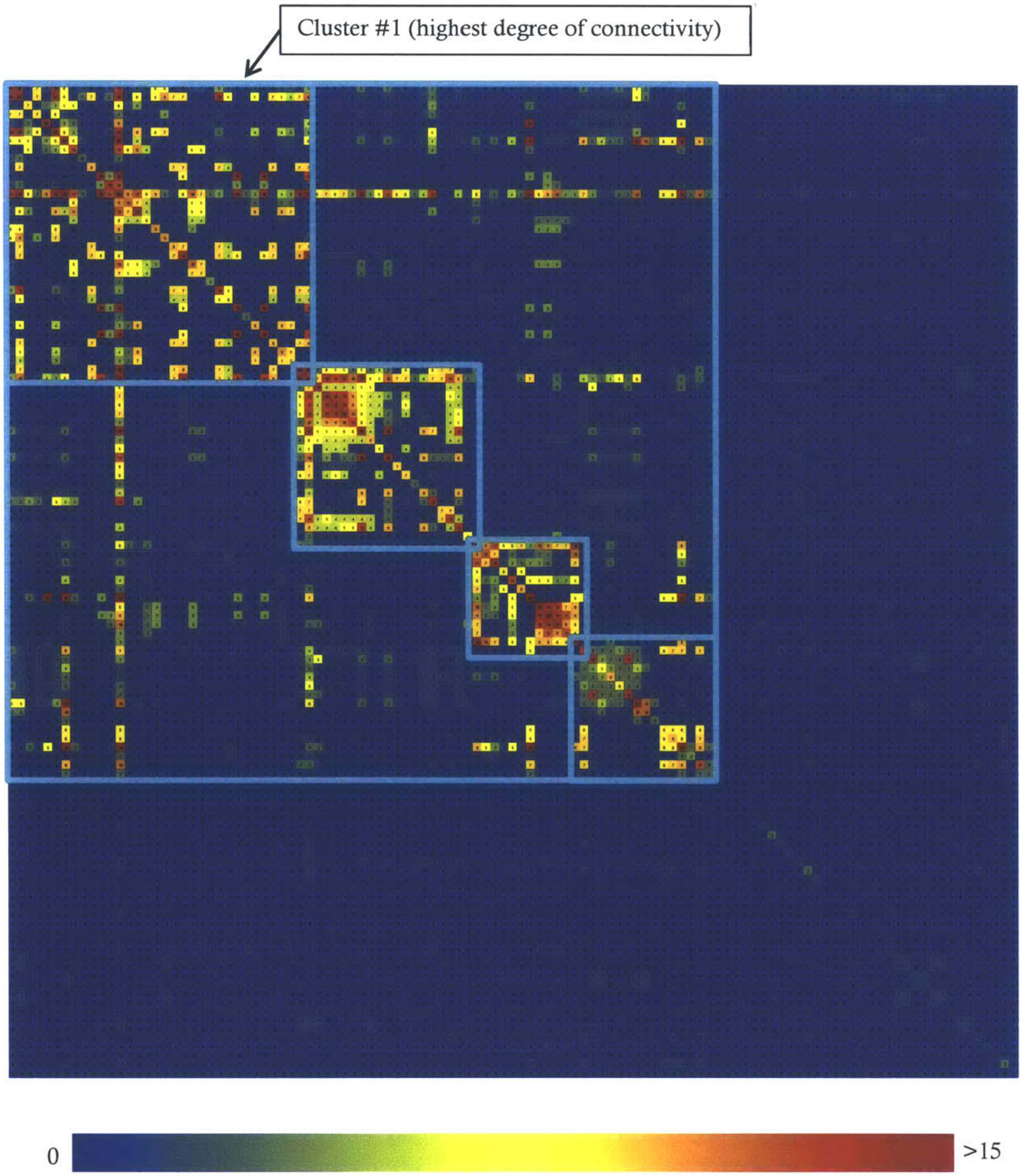


Figure #18. *"Zoomed-out" view of the clustered ECUs_DSM. Data is depicted in a heatmap scale.*

Figure #18 shows four main clusters of ECUs arranged according to its degree of connectivity, all of them enclosed within a mega-group that captures the vast majority of interactions. From that DSM, the following information is easily read:

- 75 out of 113 ECUs are involved in the vast majority of *in-vehicle features.*
- There are several ECUs that do not participate in any of the in-vehicle features that are considered in Ford's data dictionary. Thus, these ECUs exist perform basic functions that do not represent vehicle feature per se.
- Cluster #1 groups those ECUs with the highest degree of connectivity.

Next step was to take a look at Cluster #1, which is "zoomed-in" in Figure #19. From that cluster I could identify a couple of "dominant ECUs". In first place the Instrument Panel Cluster (IPC), located at row/column #14 which supports 180 features and interacts in quite of them with multiple ECUs. Second, the Body Control Module which is located at row/column #40 and supports 133 features. Also, these two modules interact in 75 features. Based on this information I selected the **IPC** to conduct a further analysis of its design process focused on the development of *in-vehicle features.*

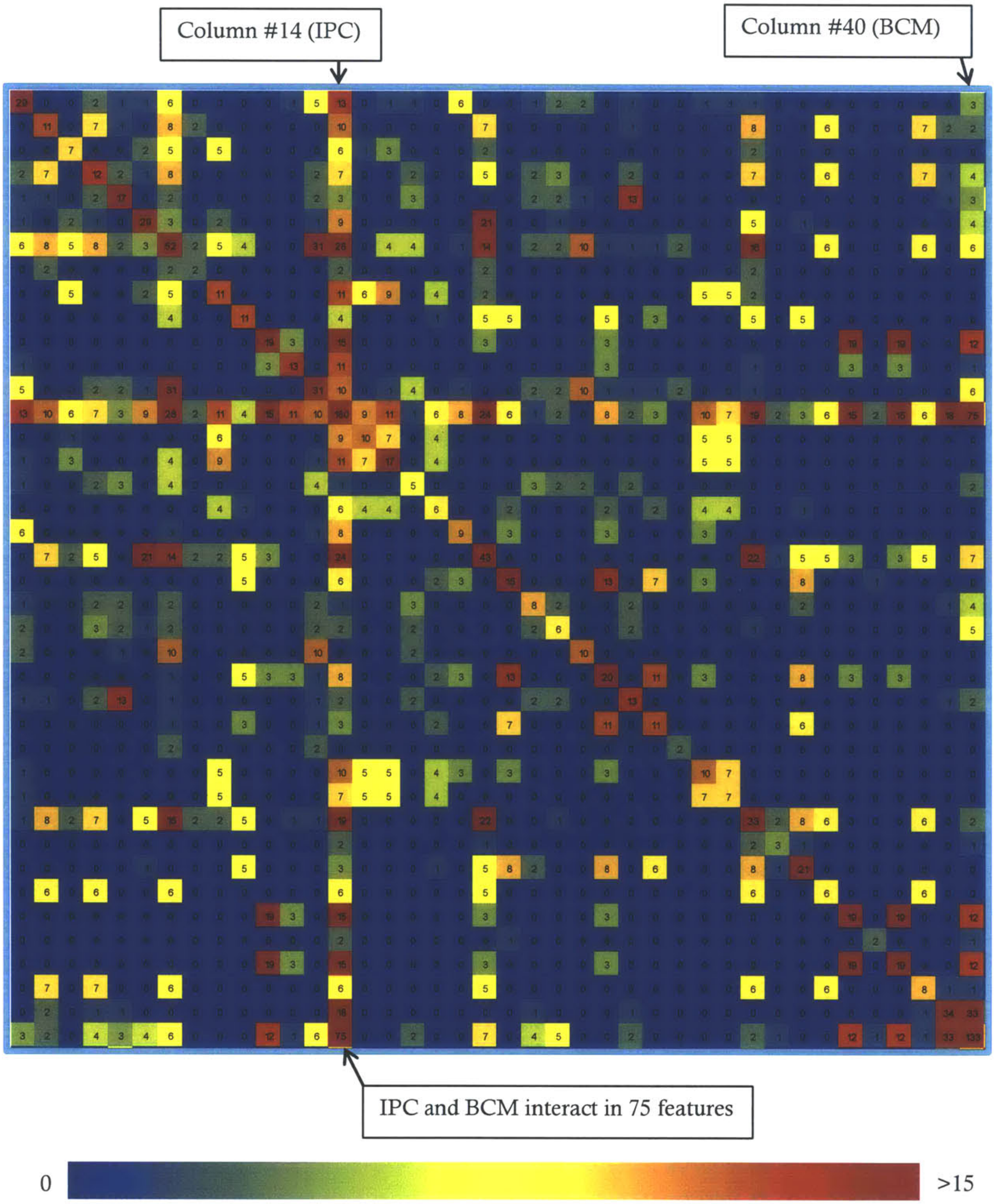


Figure #19. *"Zoomed-in" view of Cluster #1 at the clustered ECUs_DSM. Columns of IPC and BCM modules are shown highlighted.*

4.2.1.1 Development of Features in the IPC of a new vehicle line

The Instrument Panel Cluster (IPC) is the module commonly known by providing the driver with information about the vehicle status; however it performs several control functions that, if not visible to the driver, still enable the execution of many other features in the vehicle. This component is placed just behind the steering wheel as shown in Figure #20.

Figure #20. *Instrument Panel Cluster of Ford Fusion 2015*

For this research, I investigated the development of vehicle features in which the IPC has a contribution and that were part of the content introduced in a new car line that is to be launched for model year 2017. In other words, these are features developed at vehicle level that involved the participation of several ECUs –one of them is the IPC—and the research was performed by obtaining information directly from the team that developed the contribution of the IPC to those features. During the research the investigation started with those features developed for the car line of the selected project, but the queries extended to get answers considering all cases surrounding the feature development given that the IPC development team is highly experienced on this since that module supports the highest amount of features individually and collectively.

The selected car line is to be commercialized worldwide which means that; the different design variants must meet all pertaining regulations. Also, the complexity involved is vast since it will be distributed in all markets where Ford Motor Company does business.

For confidentiality reasons, the information obtained during this investigation is slightly blurred. It contains the substance that resulted from the research without providing feature-specific design information given that is out of the scope of this work.

In order to understand the strategy that is followed in both the design process and the collaboration of teams during the development of vehicle features so guided the research with the following questions:

Who leads the creation of a feature?

What are the roles and responsibilities during the vehicle features development?

What are the biggest challenges around creating vehicle features?

In regards to the project that was the source of the research, it considered the new features introduced in this car line but also features that were re-designed to offer enhanced functionalities from initial versions in past model years. The responses to the guiding questions are presented in a synthetized format and include the information obtained during the entire development cycle which took 2 years and started at the product definition and ended in the verification during the pre-production phases.

Figure #21 shows a DSM that contains the features covered during this project, they are presented in clusters the features according to the domain to which they belong and the reason to list them with a DSM format is to inform the fact that some features are interdependent.

			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Driving Mode	Comfort for stop & go traffic conditions	A																										
	Traction Control	B															X											
	Uphill/Downhill drive mode	C																										
	Adjustment of Suspension Mode	D																		X								
Advanced Driver Assitance Features	Semi-Autonomous Driving - Sensing surrounding vehicles	E									X																	
	Semi-Autonomous Driving -Lane keeping	F															X											
	Semi-Autonomous Driving - Collission Avoidance	G																										
	Semi-Autonomous Driving - Preferences Set up	H															X											
Driver Information	Audible Notifications Manager	I					X																					
	Virtual Gauge for Speed	J																										
	Virtual Gauge for Tachometer	K																										
	Tire Pressure Monitoring System	L																										
	Speed Limiting	M																										
Infotainment	Connectivity -Phone pairing	N																										
Personalization	"My Settings"	O		X			X	X		X									X									
	Memory Seats System	P																										
	Remote Start System	Q															X											
PT	Gear-Shifthing by Wire	R				X															X							
	Vehicle Towing Set up	S																		X								
	Trip Computer	T																										
	Automatic Engine set up for Ethanol fuel	U																										
PT Hybrid	Overheat Prevention System for China Regulations	V																										
	Battery Management System for China Regulations	W																										
	Fuel Door Automatic System	X																										
	Fuel Economy Computation and Display	Y																										
	Approach Detection System	Z																										

Figure #21. *DSM with the features covered in the project of the case study*

Who leads the creation of a feature?

The current feature-creation process starts with the designation of a *feature owner*, who is the technical leader in charge of steering the involved teams in the development of the component-level specifications that are to be implemented in each component that is involved. In the past, with lower complexity of features and consequently ECUs, this role did not exist and the involved teams worked together in coordination meetings where the sub-system level requirements were the place to address the alignment and integration of the feature design process. In other words rather than seeing the feature as an entity, it was seen as part of the sub-system and component level requirements within the hierarchical decomposition of the entire system.

What are the roles and responsibilities during the vehicle features development?

The designated feature owner is responsible to communicate the intended functionality to the product engineers that design and release the other components that are also involved in the execution of the feature. Every product engineer that participates in the development of the feature is responsible to cascade and create the specific requirements that its component should meet for the feature in question, and to do this they work with the core team that develops and maintains the design specifications of the entire component. One important finding to highlight here, is the fact that the designated feature owner is typically a product engineer responsible to release one of the ECUs –basically the ECU that is considered to have the most important contribution in the performance of the feature. Finally there is also participation of systems-integration teams that support the design tasks to reinforce the communication of all feature requirements and provide technical support on to ensure successful integration at the sub-system levels. Figure #22 shows a representation of the interaction of the team that is involved in the development of a feature. It shows how roles and responsibilities each player in the context of the organizational structure. Thus, in this diagram, the "component-level" and the "system-level" zones refer to the organizational chart levels depicted in Figure #8.

What are the stages of vehicle-features development?

The development of the features flows through the conventional stages of the design of the components and subsystems of the vehicle. As described in section 2.4 Ford PDP follows the "Vee" model for systems engineering, at the design phase the subsystems are decomposed sequentially until reaching the component level. Hence, during the design phase all attributes, functional performance targets and vehicle-features that each sub-system/component should meet are mapped into functional requirements that become inputs to the design process of each sub-system/component. The functional requirements detail information of both the expected performance and the integration at upper level sub-systems.

Once the functional requirements of the vehicle features are integrated into the design requirements of each component the detailed design is activity is performed and is documented in technical specifications that are delivered to suppliers who produce the components according to such specifications.

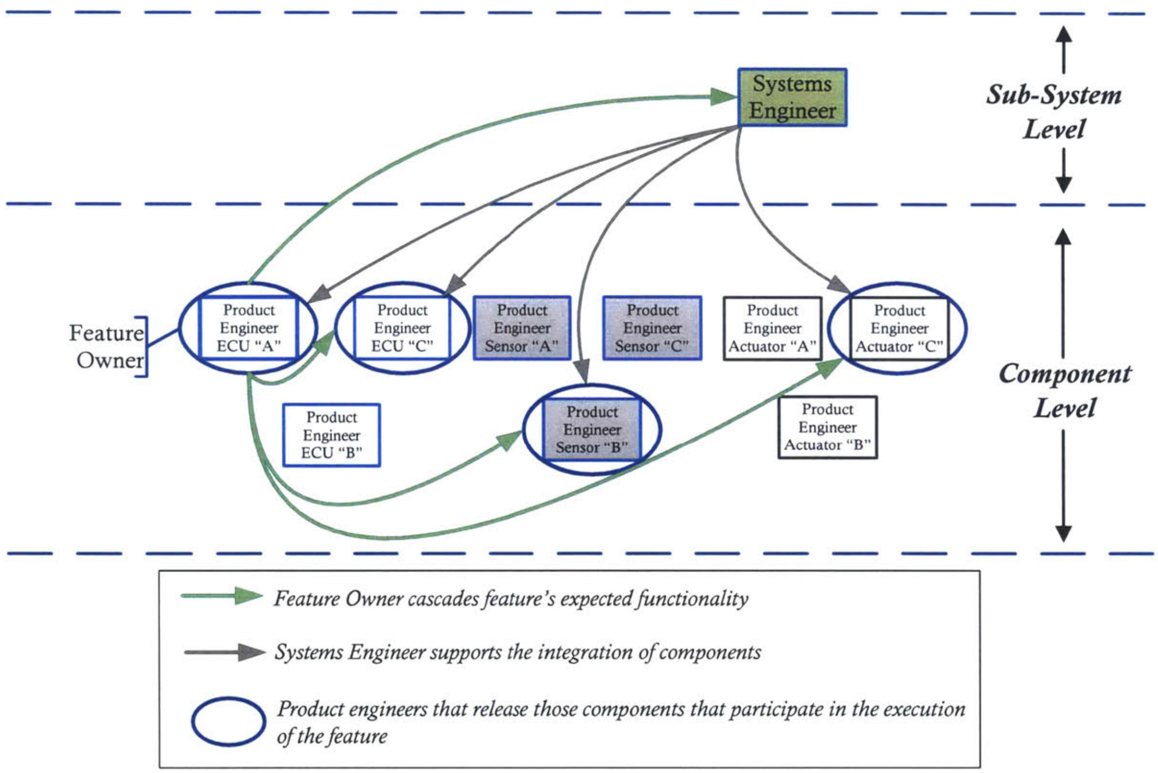


Figure #22. *Scheme of collaboration in the development of features*

In the case of the ECUs, one essential element is the software which –with exemption of couple of ECUs—is completely developed by the suppliers based on the technical specifications. During the developmental work with the supplier the product engineer focuses on communicating the functional aspects and ensures the component meets the design intent.

During the verification phase, suppliers produce prototypes that are used to assemble benches and prototype vehicles for testing. The verification of features is performed by dedicated teams that address the evaluation of components, subsystems and the entire vehicle.

What are the biggest challenges around creating vehicle features?

Developing vehicle features requires a strong capability to manage complexity. In the one hand, the features are constantly updated in its core design intent as part of the evolution of the product. In the other hand there exist always valid reasons for creating variants, so the features end up working differently among different car lines, even though the value delivered by the feature is the same, the specific implementation varies. This *necessary complexity* obeys to multiple factors that are enclosed in the need to obtain the most sustainable solution from the cost perspective.

The development of the *"Traction Control"* feature ("B" in DSM of Figure #21) is perfect to illustrate the management of complexity. For this feature two variants were created. One which integrates a dedicated hard switch to command driver's selection and another that works with a navigation menu that is accessed thru the driver controls.

Having a dedicated switch in some vehicle versions was affordable while in other vehicle versions –with more content—opting for the navigation menu avoided the cost compromise of adding an extra switch.

The biggest challenges identified in the development of features are all linked to managing complexity and after its analysis they were classified in four main categories that are summarized below:

Traceability of Regulatory Requirements

The introduction of new technologies creates the imperative to re-think how those requirements that are driven by governmental regulations should be updated. There exist a good portion of the regulations-driven requirements that were created in a period in time where the technology in the vehicles was mainly electro-mechanical, and consequently the way how they were implemented responded to that nature. However as new technologies are being introduced, the regulatory requirements need to be implemented differently. Although the regulation still requests the same concept, the way how it should be accomplished is to be re-designed with different strategies as per the new technologies characteristics. This imposes the challenge of re-designing features that should deliver the same functional concept, that was conceived under an electro-mechanical domain and translate it into a new digital environment enabled by software.

During the development of the *"Gear-Shifting by Wire"* feature ("R" in DSM of Figure #21) this situation was very evident. Anti-theft regulatory requirements had to be update to meet the concept requested by the regulation and this involved a paradigm modification to update feature's requirements and the creation of new ones. During the development process, two undesired iterations occurred after gateway reviews because it was discovered that certain functional aspects were misunderstood. Once the verification in prototypes started, two additional and non- planned iterations were needed to address aspects about the human-machine interface in which the text-messages strategy was not consistent with the way in which the driver should set the system under special procedures for towing the vehicle. While this time the regulatory requirement was not compromised still the overall design intent was not aligned to completely satisfy the customer expectations. Lastly, during the certification process by which every regulatory requirement is examined to ensure compliance, the IPC product engineer received a false test result indicating no compliance with one of the anti-theft aspects associated with the *"Gear-Shifting by Wire"* feature. In this assessment it was determined that the IPC module was not executing one needed warning and this was causing the non-compliance. After the technical discussion it was confirmed that the test procedure used was not *in sync* with the way how this feature is implemented with the new technology. This event exposed two important aspects; first, the challenges involved in the traceability when new technology is introduced and secondly the fact that not all stakeholders see the feature owner is as the primary reference in regards to the implementation of the feature under question. While in the design stages he is considered to play a major role, in the verification stages he is not because the features are not seen as entities across components but instead as components across functions and the focus then is placed in the components. This mismatch in the role of the feature owner is tightly coupled to the next item which is *accountability*.

Accountability

The investigation revealed that while the feature owner is assigned with the responsibility of leading the development of the feature from the functional perspective this is not reflected in terms of accountability. While the feature owner is seen as the master reference to provide direction about the design intent of the feature in the development phases, he is not held accountable of all the decisions he made as functional leader. This lack of accountability has important effects especially during the verification stages in which –as explained earlier— the focus is at the component and not at the feature. As soon as the testing phases commence does the tracking of failed requirements and for every open item there is always a designated champion that should lead the resolution and is formally held accountable to take that issue to closure. The criteria to designate the champion is to find out what the component that is causing the failed requirement is and assign the product engineer that owns the component as the champion. In short, the feature owner is given full control of the decisions he makes when designing the feature but he is not held accountable for the outcome of those decisions. This situation often results in features that are developed with a high number of non-desired iterations derived from feature definitions and requirements that were cascaded incompletely and that are corrected as the tests results reveal the missed or failed functions. As explained from the IPC team, there is no hard incentive to produce a very precise feature definition during the development phases because ultimately the feature owner is not impacted by the effect of their decisions unless he is designated champion as per the criterion explained earlier –which is really rare because typically the feature owner perfectly understands the feature requirements that reside in his component. The team also highlighted they believe is reasonable this to occur because in the end, the feature owner is primarily focused in releasing his component as this is what he is ultimately held accountable for.

During the development of the *"Adjustment of Suspension Mode"* feature ("D" in DSM of Figure #21) one of the requirements cascaded to the IPC module was not consistent with the requirement cascaded to the Powertrain Control Module (PCM) and this resulted in a failed requirement. The special situation here is that initially the open item resolution was assigned to the PCM product engineer who developed and worked in a resolution plan to implement the design change. However later re-tests revealed the reason of the incompatibility was not as initially assessed and after a new design review it the feature owner discovered that the incompatibility had to be resolved at the IPC side. As shared by the team members "for the feature owner it was a simple change in direction but for us this represented a very easy but late software change that compromised our software delivery schedule and that could have been avoided if the information had been cascaded correctly. Instead the status of the open item kept assigned to the wrong champion for a while."

Complete Design Intent

As the vehicle features complexity increases so does the possible operational scenarios under which the vehicle can provide an outcome. There are many features operating simultaneously at the vehicle and also a growing number of them are becoming inter-dependent, which means that a single change in one feature may have impact in other features that could cause effects that are desired and expected but also unexpected and undesired. Thus, as new features are added and some are evolved, determining all possible scenarios for the design intent of a single feature demands extensive analysis and hard thinking. Ideally, during the feature development all operational scenarios and interdependencies with other features should be clearly defined however the reality is that there are some cases where the complete set of possible operational scenarios are discovered during testing at the prototype level.

An example of an incomplete design intent definition occurred with the development of the *"My settings"* feature ("O" in DSM of Figure #21). For this project this feature was enhanced to include additional elements of personalization that are matched to the vehicle key. During the design stages the team focused on integrating the new elements and ensuring that the way how the user had to input his settings met his expectations. However after a design review with the *"Traction Control"* feature owner ("B" in DSM of Figure #21), it was discovered that in the feature definition of *"My Settings"* one scenario was completely unobserved. The IPC module team agreed this was something hard to visualize for the feature owner due to the complexity of the features involved, and the fact that the level of inter-dependency between these two features had not increased on purpose but as the result of the fact that for this car line, the variant of the *"Traction Control"* feature that was designed was unique and going for first time. This late discovery demanded an unplanned design iteration and resulted in a delayed software implementation of this feature.

Key takeaway: In order for a feature to be correctly delivered, it is mandatory it starts completely defined.

Assessment of Customer Expectations

The final category of the challenges around the creation of vehicle features has to do with the assessment of what is expected from the customer. Opposite to what happen with performance requirements where there is a right answer, when it comes to determining the right strategy for human machine interaction matters, there is no right answer. It ultimately depends on opinions and perspectives that pretend to assess what is acceptable or not. In the case of those features that involve graphical presentation of information, or strategies to communicate information such as audible visual or haptic feedback, or procedural sequences to activate a function thru controls or touch screen menus, the intended design changes constantly. It may occur that during the entire design review gateways one configuration is agreed by all stakeholders but then as soon as the tests in prototypes start the opinions change. There is a fundamental tension here, in the one hand it is completely desired to change what is necessary in order to ensure the product that is delivered meets the customer expectations, and this might imply that the change in mind occur after testing prototypes. But in the other hand, a lean and viable development of features requires the definitions to be made correctly as earlier as possible.

During this project the definition of some user-interaction aspects of the *"Fuel Economy Computation and Display"* feature ("Y" in DSM of Figure #21) changed after the initial drives in vehicle prototypes. The appearance of the information was modified from the original format due to the desire to include some graphics and modify others. While the modifications did not involve a hard change management, the fact is that this modification had an impact in both cost and schedule.

Project Overview

Finally, Figure #23 presents an overview of different paths that every feature went thru during the execution of this project how. It is presented with a DMM that relates every feature with the four categories of current challenges identified in the development process.

			I *Traceability of Regulatory Requirements*	II *Accountability*	III *Complete Design Intent*	IV *Assessment of Customer Expectations*
Driving Mode	*Comfort for stop & go traffic conditions*	**A**		X		
	Traction Control	**B**	X			
	Uphill/Downhill drive mode	**C**				
	Adjustment of Suspension Mode	**D**		X		
Advanced Driver Assitance Features	*Semi-Autonomous Driving - Sensing surrounding vehicles*	**E**				
	Semi-Autonomous Driving -Lane keeping	**F**				
	Semi-Autonomous Driving - Collission Avoidance	**G**				
	Semi-Autonomous Driving - Preferences Set up	**H**			X	
Driver Information	*Audible Notifications Manager*	**I**				
	Virtual Gauge for Speed	**J**				
	Virtual Gauge for Tachometer	**K**				
	Tire Pressure Monitoring System	**L**				
	Speed Limiting	**M**				
Infotainment	*Connectivity -Phone pairing*	**N**				X
Personalizatio n	*"My Settings"*	**O**			X	
	Memory Seats System	**P**		X		
	Remote Start System	**Q**				
PT	*Gear-Shifthing by Wire*	**R**	X	X		X
	Vehicle Towing Set up	**S**				
	Trip Computer	**T**				X
	Automatic Engine set up for Ethanol fuel	**U**		X		
PT Hybrid	*Overheat Prevention System for China Regulations*	**V**	X		X	
	Battery Management System for China Regulations	**W**			X	
	Fuel Door Automatic System	**X**				
	Fuel Economy Computation and Display	**Y**				
	Approach Detection System	**Z**				

Figure #23. *Overview of the feature development process for the project that was investigated in the case study.*

4.2.1.2 Customer Experience Development – Forecast of the Desired State

In the preceding section I elaborated in the understanding of the current status of the PD organization in regards to how the customer experience offered by an automobile is designed and developed. This analysis addressed two main elements, in the one hand the strategies that are followed during the development process and in the other hand it also outlined the way how the key actors within the organization collaborate to achieve it.

Now it is time to elaborate on the desired state for the customer experience development. In order to address the predictive adaptation of the PD organization, it is necessary to know both the current state –described earlier—and the new state for which to adapt. This desired –*new*—state is to be structured based on a forecast of the dynamics of competition that is expected to prevail in the years to come, specifically –in the development of business models in the mobility sector. Next, I describe the different elements that integrate this forecast.

4.2.1.3 Platform-based business model

The introduction of the *Internet of Things* is creating a shift in business models in almost every field. In particular to the technology businesses "platforms can be a strong source of competitive advantage" [Andressen (2011)] given the vast opportunities to connect it with services and other products and extend the relationship with the customers beyond the original purchase.

In its business strategy Ford Motor Company points to a business model in which the platform is the vehicle and the mobility solutions are enabled by a strong connectivity with the automobile. The options for connectivity are various being the most evident, the connection with cloud-based services but it can also be anticipated the connectivity with other vehicles and public infrastructure –specifically for autonomous driving—but specially with other products such as mobile phones and tablets. In Figure #24 it is shown a graphical representation of how Ford's business strategy maps to a platform-based business model.

One key element for a platform business model to be successful is the attraction and consolidation of large number of users because this will position the platform as dominant and the effect will be the attraction of more services. To achieve this it is essential to focus on the customer experience because, *the winners in the digital economy will put the people first [Accenture Tecnology Vision 2016 People First: The Primacy of People in a Digital Age, Accenture (2016)]* and this means to exceed customer expectations not only with the benefits of a good product but with a continuous experience derived from it. This is to be central for the platform dominance.

In order to develop a unparalleled customer experience, it is necessary to design it following a holistic perspective. Focusing only in how the customer experience is delivered through the automobile (the platform) is not sufficient in this context.

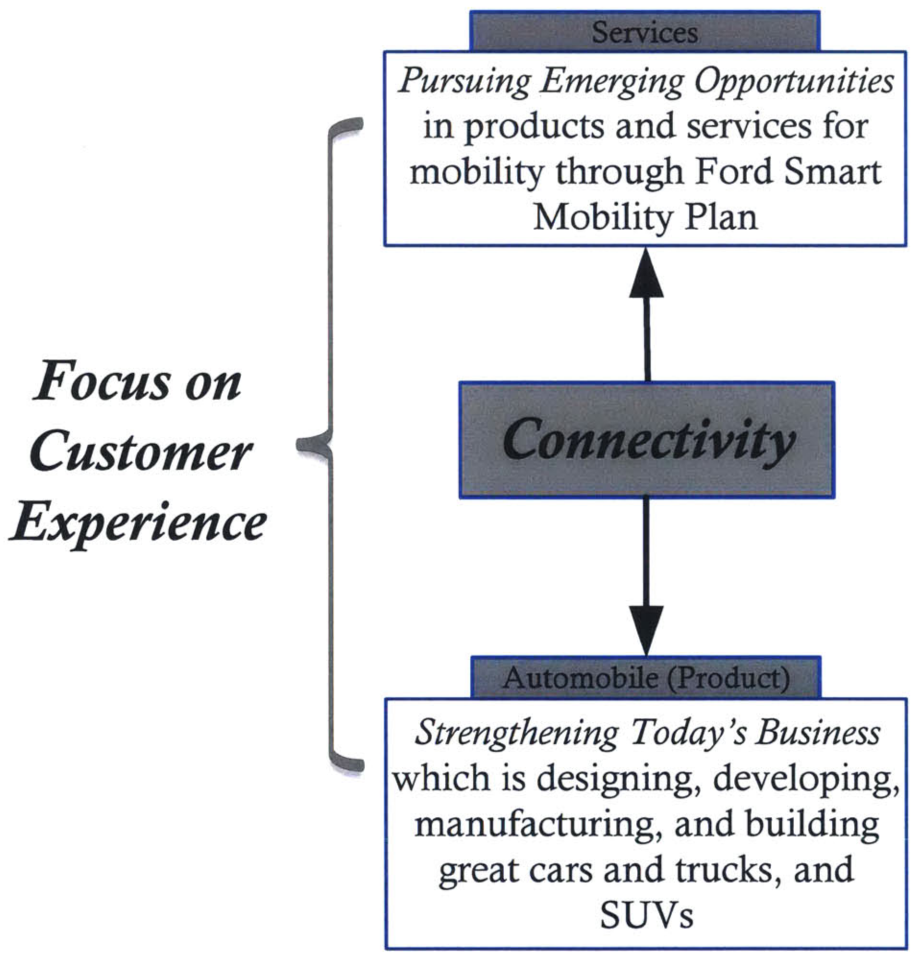


Figure #24. *Mapping of Ford's business strategy to the Platform-based business model*

Thus it is imperative to address the customer experience development with an integrated approach that considers what is delivered in the vehicle and how the features at the vehicle can be mapped to services or other products. Also, it requires including smart strategies to connect both domains efficiently. What follows is the breakdown of the key characteristics in the development process of the customer experience that point to be instrumental in attracting platform adopters.

4.2.1.4 Personalization

During the literature review I found a clear convergence about the levels of personalization that are expected by the customers in the future products. It is clear that customers today participate actively in the innovation of products and services. A clear example is what happens with Apple's iPhone, which enables the users to create their own apps and extend the capabilities of the device while obtaining the desired level of customization. Giving the customers the option to personalize their vehicle and with it the features it offers is a strategic element that must be considered in the development of vehicle features. It is expected customers to be looking to make use of the information produced and available from their automobiles for multiple proposes which include the personalization of vehicle features and its connection with additional products and services beyond the vehicle.

4.2.1.5 Updateability & Reusability

Selecting the right product is an assessment that will become crucial in a platform-based eco-system and one of the key elements in making such assessment will have a great deal with the updateability and reusability offered by the product. It is a reality that users are accustomed to get software updates for the electronic products they use most like smartphones, tablets, computers, wearables, et cetera, and this trend will continue. So, it is expected that customers will demand from a vehicle –which runs on software—similar levels of updateability that allow them to add more content to it specially as new services or devices are released.

4.2.1.6 Nimble software development

Updatable products demand a superior development of software, basically in an IoT ecosystem, which is where platform-based business models thrive, *every industrial company must become a software company* [Porter, Heppelman (2015)]. For Ford it will be necessary to develop software that is not only updatable but also lean, efficient and with top level of security to avoid the flaws that could cause a deterioration of the platform's reputation (in this case the automobile). As new applications and electronics products will be generated constantly, it will become instrumental to be capable to add new functionalities to vehicle's ECUs in a fast and precise fashion.

4.2.1.7 Product perfection trough experimentation

Agility to produce new prototypes quickly and even utilize products in the field to continue data collection and refinement of products by testing new designs on them is a strategy that points to become a key advantage for those companies capable to operate in such format. Currently some companies have created groups of users known as *"love group"* that are integrated by highly engaged users that collaborate in development of the product with the side effect of promoting the acceptance of the platform among common users [Fur (2016)]. However another way to seize this contribution of such users is by enabling them to multiple experiments of a variety of versions of the product or new applications in real environments and situations so they can provide valuable feedback to the development teams. Big data and cloud services are the key enablers that will allow an efficient collection and analysis of real-life data that can be used to evaluate the right content in the product. Running multiple alternatives in formal experiments demands a solid traceability of features and functional requirements in order to produce all desired alternatives rapidly and robustly so by the time the decision is made on the desired new content, this can be deployed immediately. This is important to keep in mind because it will not be enough to truly find out the right application or feature but being the first to deliver it to users.

4.2.1.8 Management of large complex systems.

In an eco-system where a platform integrates multiple products or services from different players, it is important to have a precise and agile management of the associated complexity. However we can expect an environment even more complex than that in the years to come, because it's very likely to see an eco-system that will integrate platforms with platforms. In the one hand –as introduced in section 2.8—there are many technological trends that seem to converge and overlap very soon, and *many players with a varying pace of speed and innovation. Convergence of technologies may lead to convergence of industries in which eco-system participants will need to compete and collaborate at the same time [Self-driving cars: The next revolution, KPMG (2012)].* In the other hand, the speed at which customers will demand new products and enhancements will at least be the same that is currently delivered by smart phones and tablet producers which contrast with the delivery time in the automotive industry. These two factors; increased pace of innovation and the collaboration and competition with multiple players in many industries will demand a highly accurate and nimble management of requirements to deal with large and very complex systems. Where designing for the entire set of possible scenarios created with the combination of different products will be very complicated and, where ensuring that all safety standards and regulations are successfully met will separate the platforms into two categories; the trustable and the non-trustable.

4.2.1.9 Relationship with suppliers

This desired capability opens up a question in regards to the way to conduct business with suppliers. As commented earlier, with couple of exceptions, suppliers of ECUs produce them as a single end item which means they deliver the hardware and the software. But in line with the need to deliver SW-based features faster and with the needed reliability (due to an eco-system in which the automobile connects with multiple services and products) it is reasonable to think that the current paradigm will be modified and automakers will develop the software of its own ECUs although they would not like to produce the hardware of the components. Another reason to think of this new paradigm has to do with trust. Companies looking to play in the automobile platform-based business model will have to be held accountable for the security of applications (highly software-based) and for the compliance with all regulations. It is envisioned that companies looking to position their vehicle platforms as dominants will have to establish and maintain a solid reputation that will generate the trust of users

4.3 Design of a disruptive adaptation proposal

At this point I have elaborated in the current state in the development of vehicle features and I have sketched a forecast of the dynamics in the mobility business that outlines the elements that will be critical in the development of the vehicle features that play a major role in the creation of the customer experience that Ford considers a clue to succeed in its mobility business. The findings in both current and future states are key inputs for the design of the predictive adaptation of the Ford's PD that is elaborated in this section.

Concept

Every design is the realization of a concept and the case of designing a predictive adaptation of Ford's PD will not be the exception. In order to select the concept I worked with a fundamental question that I resolved with my own assessment and in which I made use of key concepts that I elaborated in chapter 2 as well as the research performed for section 3.II.

Based on the scenario described in the forecast what could be the most suitable scheme of adaptation that Ford's PD Organization should adopt in order to acquire the needed capabilities?

In conventional platform-based business models the platform product has a complexity relatively low compared to an automobile. There is simply so much technology and *knowhow* inside the development of an automobile that to my analysis, its transformation into the mobility-services platform should be addressed with an evolutive approach. For this reason I consider that Ford PD Organization should evolve its current structure and strategies and tailor them towards gaining the capabilities for a superior development of products and connected services allowing the company to *change the game* in the mobility business.

I consider that merging with or acquiring a software company are not better options given that any of those represents to get together two major players that speak different languages and this looks as an unnecessary challenge associated to create synergy in the platform-based strategy and doing it at an accelerated pace which is characteristic of the level of disruption brought by the digital era. I think a merger or acquisition would require lots of attention to the synergy efforts that can be better utilized in shaping the evolution of Ford's PD Organization. As a reference I consider lessons from the past, especially in the merger between Daimler and Chrysler which resulted in an epic fail even though they were two companies doing the same business [Nussbaum (2007)].

With this fundamental question resolved, and with the intention to design a predictive adaptation proposal to prepare Ford's PDO for delivering an unparalleled *in-vehicle experience* that flows and harmonically connects with the mobility services in order to *change the game* in the mobility experience, I present the design concept with the *to-by-using* scheme:

<u>To:</u> Stunningly adapt Ford PD Organization

<u>By:</u> Disruptively evolving its *In-Vehicle Features* Development Capabilities

<u>Using:</u> the forecast of the expected dynamics in the automobile platform-based business models

Consistent with the *systems thinking* approach used in the development of this work I make use of the Object Process Language (OPL) to represent this predictive-adaptation concept shown in Figure #25.

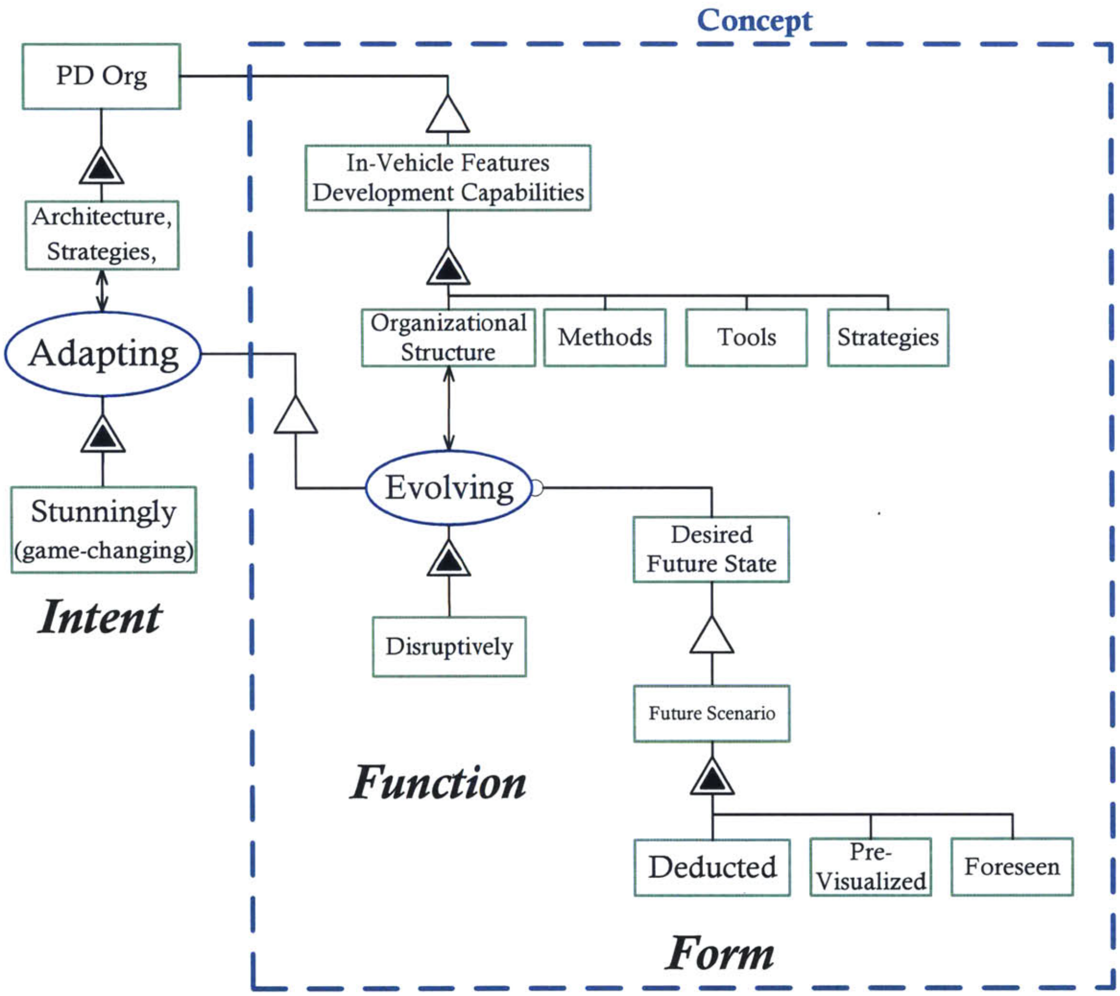


***Figure #25**. OPM representation of the concept for the predictive adaptation proposal*

The next stage is to elaborate in the different components of the predictive adaptation design, which includes the organizational structure, the strategy, the tools and the methods that the organization should follow for the development of *In-Vehicle features*. As outlined in the concept, the organization shall evolve, and a very effective way to explain this evolution is by describing first the proposed strategies that will make use of methods and tools. Explained in this order the structure needed in the organization will become a logic choice.

4.3.1 Strategy for the development of *In-Vehicle features*

When developing *in-vehicle features*, it will become substantially important to do it with a clear mindset that what is done goes beyond a car feature or functions performed by components of a system. It must be seen as the mission of creating an *in-vehicle experience* aimed to connect with the users and provoke them to engage. The leader in the development of in-vehicle features should be fully convinced that a successful *in-vehicle experience* is the key enabler for a superior mobility experience that will result in the platform adoption and dominance. He should play the role of a designer, a specialist in the entire experience that the feature creates and with a focus on constant innovation. He should have the power to make what is necessary for taking his feature to the next level no matter what that means, which includes but is not limited to add more interactions inside and outside the vehicle, someone who sees the big picture of mobility and is willing to take risks and move fast in order to deliver great experiences. He should be the most informed individual in the organization about everything that happens around the feature, from all perspectives. He should be the master reference and first point of contact for anything concerning the *design intent* of his feature in the entire eco-system; vehicle and connected services or products.

I suggest the development of features to follow a *design thinking* strategy [Brown (2009)], in which the feature owner leads the entire cycle; inspiration, ideation and implementation around the *design intent.*

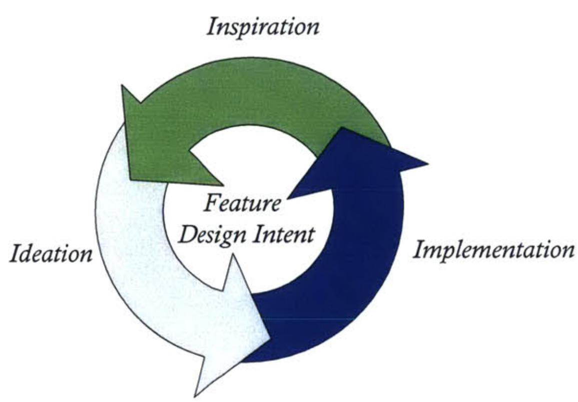


Figure #26*. Design Thinking strategy for in-vehicle features development*

As commented in section 2.6, design thinking is an approach that focuses on fully understanding the user experience. The innovation is produced by centering in the user and deeply understanding his needs, tastes, passions, problems, et cetera and from them creating designs that not only satisfy the needs or solve the problems but that also deliver an experience that connects with the user. In this proposal, the *end product* that the feature owner creates it the *feature design intent*.

The ***Inspiration*** phase is about getting insights around the experience to be delivered, in this stage the feature owner should lead the generation of the ideas and collect data to build the knowledge about the feature. In order to create concepts he should employ all kind of resources available which include participation in customer clinics, socialization of proposals with colleagues from all areas within the company, intensive discussions and analysis in cross team design reviews as well as contact with real customers in order to empathize and fully understand what the type of the experiences they like and expect around a vehicle.

During the ***Ideation*** phase, alternatives for the design intent are explored and tried out. This stage is about prototyping solutions rapidly and identifying the best one with the certainty that is obtained after experimentation. During this phase the feature concepts should be communicated with compelling demos that engage all audiences and invite them to contribute or challenge the concepts in order get them even better.

In the ***Implementation*** phase the feature owner delivers the selected design intent that is clearly expressed and documented. He works with the stakeholders involved in the implementation of the feature throughout the entire system and across components. The final deliverable –the design intent—is a solid document that is complete, accurate, and –most importantly—correct.

The cyclic nature of the design thinking strategy –as proposed here—is meant to represent the fact that the feature is in constant innovation, and it's intended that for every car line in which the feature is implemented the feature owner goes thru the three phases to ensure that result is a better experience that is enriched with new information from customers in the field and by the creative work to bring something new in every car line.

Now it is time to comment on the proposed method that will enable a nimble execution of the design thinking strategy for the development of in-vehicle features, specifically its deliverable; the *design intent.*

4.3.2 Methods

Given the current complexity that will reign in the platform-based business model, and considering the need to communicate the feature *design intent* in a precisely fashion across different layers of Ford's PDP the proposal is to work with model-driven methods in order to address the following tasks:

♦ **Clear communication of proposals during the *inspiration* phase**. From the forecast described earlier, it is expected that the number of stakeholders to be involved in the development of in-vehicle features will increase as and will demand a scheme of communication way better than text-based documentation and free of ambiguities that static diagrams fail to prevent. According to the forecast described in section 3.II, the creation of the mobility experience will start with the in-vehicle experience but will extend to other services (apps or connection with other products) added on top of the platform –the vehicle—that completes the experience. The winners will be those ones who seamlessly couple the platform and the services. Clear communication with stakeholders either at the vehicle level or at the services level will be instrumental to achieve this smooth integration. During the ideation phase it will be necessary to go thru iteration loops in order to craft better proposals and this will occur with stakeholders with multiple backgrounds and perspectives, so in order to promote the iterations to occur quickly and precisely, all stakeholders shall speak a common modeling language.

♦ **Rapid prototyping to support the *ideation* phase.** In-vehicle features will be prototyped by running executable models for all proposals. Multiple experiments with varied conditions or settings will be analyzed with these virtual prototypes in order to find better solutions faster. As features will be software-driven and creating more mature prototypes –such as mock ups for clinics—will require fast cycles of software development. Working with a model-based method will allow a streamlined specification of requirements for software prototypes by avoiding the reworks due to misunderstood requirements.

♦ **Robust verification during the *implementation* phase**. The completion of the feature development will end once it is completely verified. This includes the confirmation that all possible scenarios where the feature may operate are detected and covered with valid actions. To achieve this, it is necessary to execute a solid analysis of requirements to verify that there is not any conflict among them and that there is no missing requirement at any scenario. Using a model-driven approach for the validation of the feature will be the right practice to execute this analysis robustly and in a timely manner. Once verification is complete, the feature owner will have been finished his development work and will hand off the model of the feature which represents the *design intent* and will become the master reference for any stakeholder. This does not mean that the feature has been implemented already across all involved components but is just the kick-off to cascade the feature development to lower levels of decomposition, to the specific functions each component perform are developed.

Next, I present the proposal of the tools that shall be used and that in conjunction with the method will enable the execution of the strategy.

4.3.3 Tools

In order to develop the feature in a model-centric paradigm, it necessary to use tools for modeling requirements, scenarios, events and states because at the moment of creating the experience, these are the elements that are used to describe it in relation to the customer. In this regard, the proposal is to employ SysML™ as the language to express the *in-vehicle feature design intent*. Proposing this language obeys to the fact that its utilization has spread in other industries such as aerospace –in which the complexity of the projects is tremendous— and as a result, there exist today several companies that offer commercial tools for modeling in SysML™. This growing adoption, suggests that SysML™ is becoming the standard modeling language for complex systems, and thus it will be the common communication language among the different players in the platform-based ecosystem.

It is important to recall that in this proposed model-centric development of features, the feature models (expressed with SysML™) should be managed with a strategy that emulates the same paradigm that is practiced in the design of the mechanical hardware of the vehicle, where 3-Dimensional models of all components are assembled virtually. Put it simple, the "in-vehicle feature design intent" is virtually created in a model. This means that every stakeholder or team member of the PD organization should be able to access it for any particular interest he might have. For instance, some team members will access it to learn the engineering direction that applies for the design that their respective components should meet, while others will access it to get executable representations of what the feature does and how it works and then communicate the *design intent* across other teams.

In the case of CAD models, they contain the exact information of the spatial distribution of the components within the vehicle. Every stakeholder that needs to verify a dimension of a part, or maybe perform an assessment of the roominess of the vehicle will access the CAD model to obtain that information. There is no ambiguity in the CAD model; any available space existing in the model will exist if all components are built to print and the assembled. Every team member knows that any proposal that is compatible in the CAD model is geometrically buildable. If someone wants to package a component he can directly work on the model with the certainty that what fits in the model will fit once the components are assembled.

The 3-Dimentional model presents the complete information of the spatial distribution of the parts and this allows cross-functional team members to work independently with no need for the CAD author to tell them what they can or cannot propose.

Of course, understanding CAD models does not represent a big challenge because the geometric information expressed in those models requires the use of the visualization capabilities that humans use every day. However the relevance of this paradigm becomes more important when translated to the domain of *in-vehicle features* (experiences). In this domain the information is more complex to process. In some cases capturing the entire mode of operation of an *in-vehicle feature* could be very challenging since this implies to describe behaviors under multiple scenarios and circumstances. Thus, communication with SysML™ models demands the understanding of a language that certainly has a graphical syntax but whose semantics is not obvious.

A central element of the model-centric paradigm is that the revisions of the models are arbitrated and tracked rigorously in order to ensure full control of design changes. Certainly every stakeholder can work over a published model but only in a "read mode", since only the owner of the model shall revise it and thus ensures feature governance. In the case of the in-vehicle features models the proposal is the feature owner to be the only one with the authority to revise the *design intent* and then update the model. Figure #27 shows the parallelism between CAD and SysML™ models under the model-centric development paradigm.

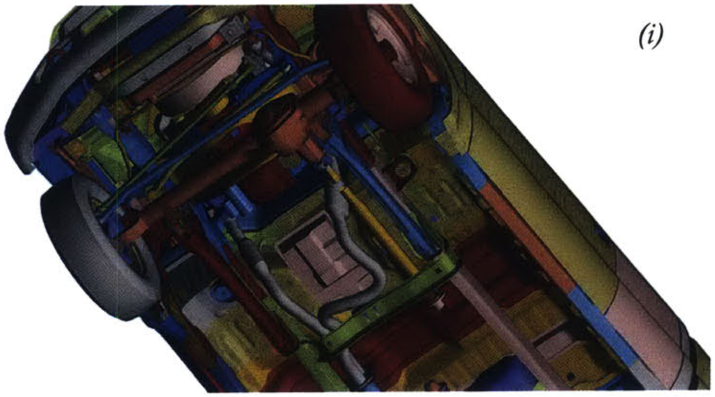
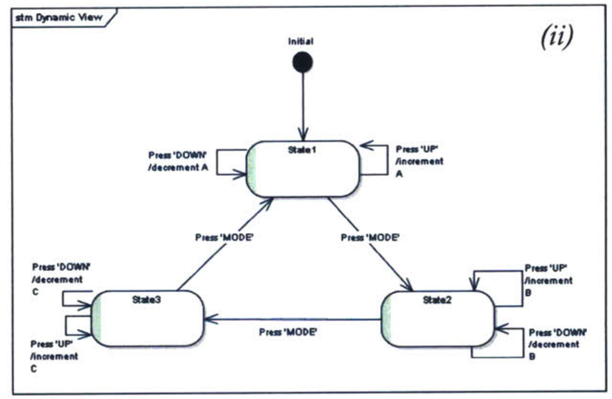
CAD models (as is)	SysML™ models *(as proposed)*
	
Stakeholders access the model to get information about the geometrical distribution of all kind of components, they can inquire information from the model like volumes, distances and surfaces.	Stakeholders access the model and understand what the feature is about, what ECUs are involved and what the interfaces are.
Design team members from diverse sub-systems and components can evaluate packaging proposals under the assumption that what fits in the model is geometrically buildable	Design team members can evaluate new proposals of events and add activities for the feature under the assumption that if the simulation produces valid results, the proposal is a feasible alternative for further exploration.
Design team members rely on what exist in the model is the only single version of the design, so as long as the design of its component is aligned to the model, there is system consistency	Design team members rely on what exist in the model is the only single version of the feature and the only single source to feed the design activities of all components involved. So as long as their components (e.g. the ECU) meet the requirements stated in the model consistency is granted
Only the model owner has the authority to revise the design information (hence the model). Revisions are welcome and expected to occur due to the iterative nature of the detailed design process but they are conducted after design reviews and concurrence of all stakeholders	Only the *in-vehicle feature* owner has the authority to revise the *design intent* (hence the model). Revisions and the generation of multiple competing variants are welcome and necessary during the *inspiration* and *ideation* phases. During the *implementation* phase, revisions are expected for exceptional cases but should occur based on trade off analysis to and with concurrence of all stakeholders

Figure #27. *- Model-Centric Development Paradigm, parallelism between CAD and SysML models. Picture sources:*

(i) http://www.altairhyperworks.com/product/HyperMesh

(ii) http://www.jhuapl.edu/ott/technologies/docs/modelingwithsysmltutorial.pdf

Another important property the tool should contain is the capability of integrating the descriptive model –the *design intent* model—with models and tools at other layers of the vehicle development process. Since the *feature* is a vehicle-level requisite, this means that its descriptive model is located at the top of the system decomposition, hence further integration should occur with the eco-system of models and tools that are currently in use in the development of the sub-systems and components, which includes control-design models.

Referring to the current practice with CAD-based model development, what occurs is the CAD models are seamlessly taken to other tools and environments of design activities of several types that include Finite Element Analysis (FEA) for thermal, mechanical, electromagnetic conditions at both component and sub-system level which also include vehicle dynamics, noise and vibration, mechanical impact etc. Also, in terms of fabrication, CAD models are also connected to manufacturing tools and systems that produce the components either with CNC (Computer Numerical Control) or 3D-printing machinery.

In the case of *in-vehicle features* which are mainly driven by embedded-software applications what it will be necessary is the descriptive models to integrate with tools and models used to design and implement embedded software. For many years, the automotive industry has utilized these types of models in both supplier and OEM sides. In the one hand there are modeling tools for control design, which are used to develop the algorithms and the logic that is applied to process sensors, signals and driving-controls inputs. In the other hand there are software modeling tools to architect the embedded software that will execute the control algorithms, these models are utilized to auto-generate optimized code and to address its integration with the electronic hardware of the ECU during the implementation phases. Figure #28 shows the parallelism between the current development of the mechanical hardware of the vehicle (CAD-model centric) and the *proposed* development of in-vehicle features (SysML™-centric).

The proposal described here has been developed with a tool-neutral approach, since the selection of a specific tool is not the scope of this work. However as commented earlier, it is suggested that the selected tool should comply with these two main characteristics; incorporation of SysML™ language and integration with modeling tools for control-design and embedded-software architecting.

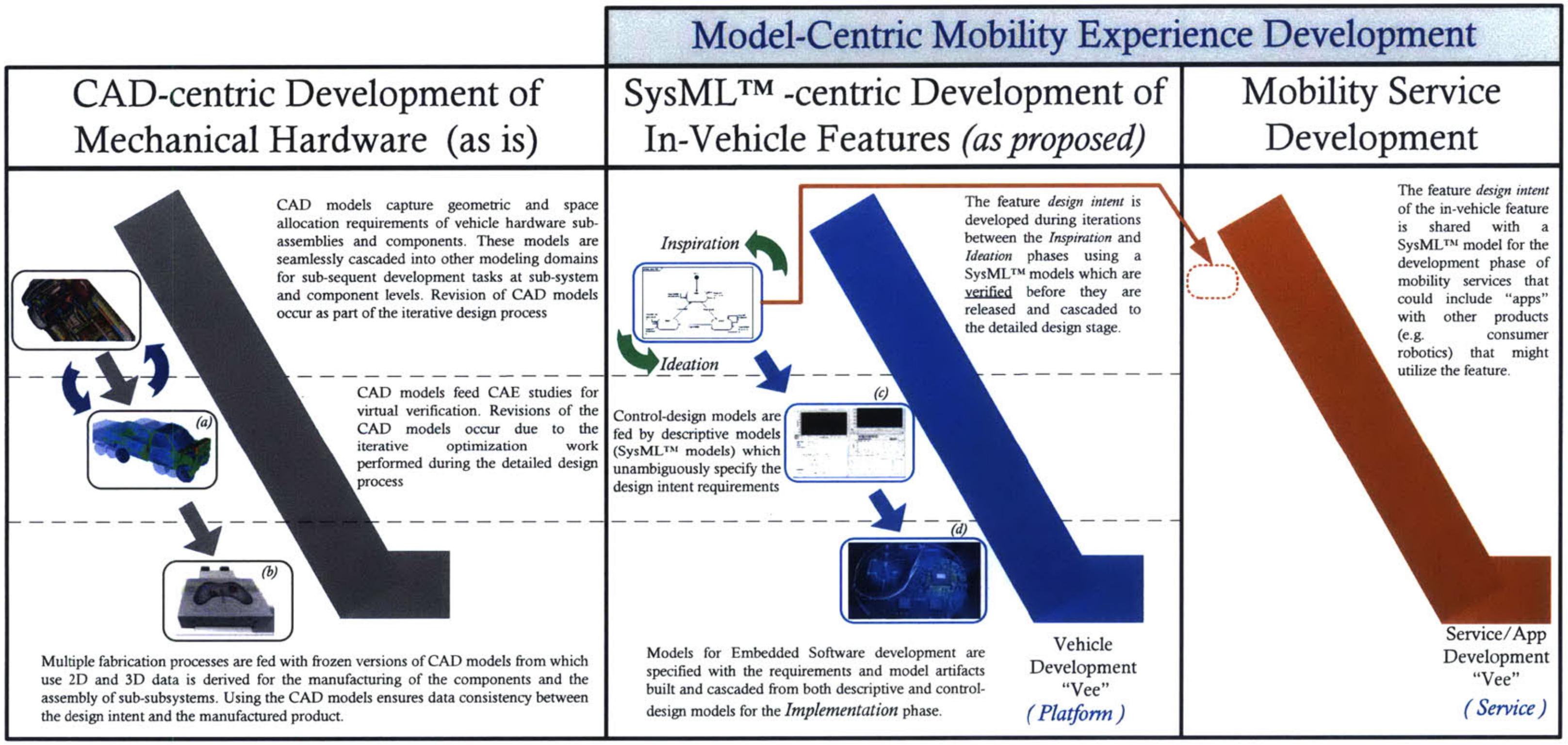


***Figure #28**. Model-Centric Development Paradigm , parallelism between the CAD-centric development of mechanical hardware and the SysML™-centric development of in-vehicle features. It is also shown the linkage to the mobility experience development. Picture sources:*

(a) http://www.directindustry.com/prod/msc-software/product-6042-493371.html
(b) http://www.autodesk.com/products/cam/overview
(c) http://www.ni.com/white-paper/11281/en/
(d) http://www.intel.com/content/www/us/en/cofluent/intel-cofluent-studio.html

4.3.4 Organizational Structure

In the previous sections I have described the strategy, method and tool that I propose for a predictive adaptation of Ford's PD Organization that has the focus to evolve its capabilities in the development of *in-vehicle features* which constitute a key pillar in the creation of the customer experience that Ford wants to provide in its mobility business. Now it is time to address the organizational structure that I propose to better execute the *in-vehicle features* development strategy.

The alignment of resources needed to accomplish the mission and the strategy of an organization is known as structure or architecture. In order to determine the alignment of resources it is necessary to address the position of the feature owner who is intended to play the lead role in the mission of developing in-vehicle features.

4.3.5 Feature Owner Roles & Responsibilities

As described in Figure #27, the proposed strategy demands that *in-vehicle features* to be managed as entities themselves. Certainly they are the ultimate expression of the harmonic performance of many components –predominantly ECUs—however in order to successfully execute the proposed strategy they must be seen as a single "product" (the experience) that seamlessly flows between the platform and the services. Thus, the feature owner should be able to work from a holistic position that allows him to focus his efforts in two main **roles**:

Designing the experience by following the design thinking strategy

Integrating the development of the component's contributions within the vehicle (the platform) and with the out-of-the-vehicle applications (services).

In order to succeed in his mission with a *"game-changing"* execution it is imperative to place him in a position that allows him to deepen his knowledge and competencies in both activities.

In regards to ***designing*** the experience, what should occur is the feature owner to deliver *in-vehicle features* with top levels of creativity and innovation. He should adopt system's mindset to see the entire experience that flows between platform and service and design for that level of synergy. Per the design thinking strategy, he should empathize with the users to fully understand the essence of the experience and get the insights to and craft compelling designs that meet and exceed customer's expectations (verify the *design intent*). But for great designs to flourish it is necessary dedicate time and space for creativity to grow, which involves to learn those things that are not obvious [Masrkman (2015)]. *Many of the world's most successful brands create breakthrough ideas inspired by a deep understanding of consumer's lives and use the principles of design to innovate and build value* [Brown (2015)].

For ***integrating*** the development of those components that build the features, it is mandatory to speak the language of systems. During the development of the feature's design intent he must do it with an integral approach to:

Make the right decisions regarding the allocation of functions among components

Specify the design intent with complete, consistent, accurate and correct requirements

Define the best interfaces to enable a robust and efficient coupling of functions.

Validate that requirements and interfaces meet the *design intent*.

Given that this integration effort will occur in the context of a high complex system –the vehicle—is that the communication channel that is proposed here is the usage of SysML™ language, because this is a tool that will allow the feature owner to perform these activities without taking the sight out of the design. The main objective is the feature owner to master this duality; a designer that is capable to communicate his design intent in the appropriate language of the embedded-software applications. Ultimately his deliverable also represents the blend of this two roles; it is a *design intent* expressed in SysML™ language.

As mentioned in Figure #28, during the vehicle development process the release of the feature *design intent* is proposed to occur at the highest level of decomposition. The iterations during the ***inspiration*** and ***ideation*** phases finalize with the verification of the design intent and the validation of the descriptive model, which then becomes the starting point from which the components involved will develop the detailed design. In this proposed strategy, the feature owner performs his work in the left side of the systems "vee" of the product development process. What occurs after the release of the feature design intent is responsibility of the product engineers that own the components.

With that said, the statement of **responsibility** for the feature owner is proposed as follows:

The feature owner shall be **responsible** of releasing a validated model of verified *design intent* of the *in-vehicle feature*.

The proposed roles and responsibilities that have been described above do have a direct implication in the structure of Ford's PD organization. In this predictive adaptation proposal the feature owner shall have its own domain; the Figure #29 depicts the fit of the feature owner in the scheme of collaboration within the context of the Ford's PD organization that derives from his roles and responsibilities.

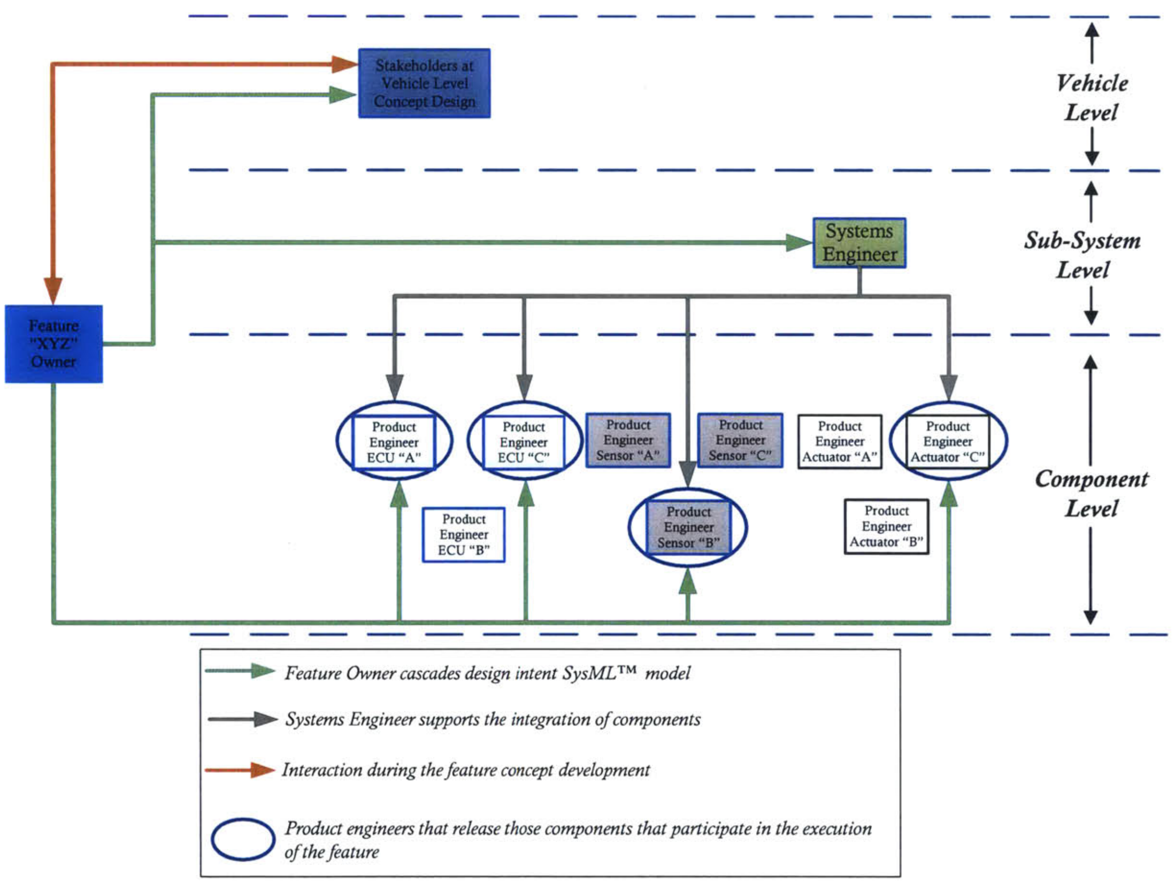


Figure #29. *Proposed scheme of collaboration for the development of in-vehicle features*

In the scheme of collaboration proposed in Figure #28, the first aspect that contrasts with the current collaboration scheme described in Figure #21, is the fact that the feature owner that is not directly linked to a functional group within the product development organization.

Consequently, the immediate question here is:

How should the feature owner position map in Ford's Product Development Organization?

The proposal is that the "*in-vehicle*" features development team should be constituted as a group that works across the different functional groups that develop components and subsystems. The reason is for that is because the direct stakeholders with whom the feature owners will deal are the product engineers that design and release the components that participate in the feature execution. However, given that the feature owner should develop the feature for all different car lines; this also represents an involvement across projects. Thus, the proposal is that the "in-vehicle" features group to be allocated with the same format that is followed by the project oriented teams. In this case this group will report to the Systems Engineering and Components leadership and to the projects management leadership. This proposal is depicted in Figure #30.

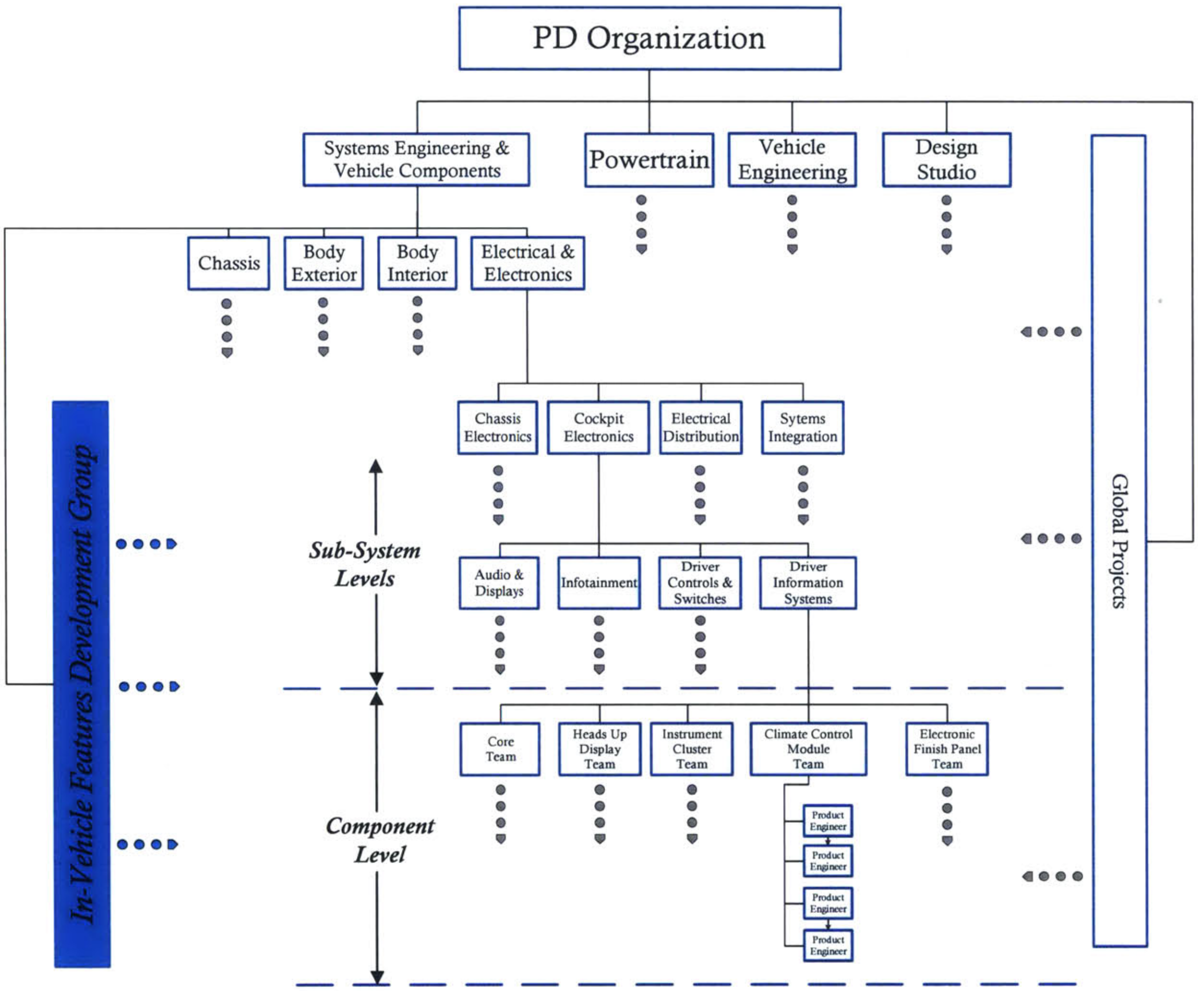


Figure #30. Proposal for the allocation of the "In-Vehicle" Features development group in Ford's Product Development Organization Structure

V. CHAPTER 5: DISCUSSION AND CONCLUSIONS

5.1 Discussion of the disruptive-adaptation proposal

The adaptation proposal designed in this thesis represents a genuine work in the forecast-based manner to adapt business firms, specifically product development organizations. The main contribution in this regard is the proposition that enhancing the practice of product development is better achieved when it is addressed from a holistic perspective in which either the improvement, optimization or enhancement of the product development practice is in essence an adaptation of the product development organization. Seeing it from the *adaptability lens,* allows us to create enhancements that go beyond the traditional *"gap-filling"* approach of fixing issues using information from the past, and opens up a broader –yet richer—set of alternatives to design solutions that not only prevent issues to occur but that also can *change the game* .

The design of this adaptation considered both the *current* state and the *future* (desired) state of the capabilities to design *in-vehicle features.* Consequently, this adaptation proposal is meant to be responsive to the challenges in both stages. Thus, it is believed that applying it today will allow the organization to overcome the biggest challenges faced in the present at the same time it gets ready to disrupt the mobility customer experience.

Another important contribution is the fact that this proposal was crafted considering the two levels of the organizational management.

On the one hand the **strategic management** which is in charge to set the course, to determine the right direction towards which focus the organization efforts, resources and bets. Here the proposition is that even though the strategic management of a firm is not within its Product Development Organization, the management of the latter must actively synchronize with the strategic direction and continuously work to adapt in order to enable the firm to succeed. From the technical side, the Product Development Organization should work on predictively identify the key capabilities that will be needed to deliver future products in a robust and agile way.

In the other hand, the **operational management** which is in charge to get things done to arrive to the course that strategic management has set. During the development of this thesis it was clarified that a product like an automobile is a serious challenge. Today's automobiles are large-scale complex systems and it is mandatory to address them with solutions at the same level of scale. The development of complex technological systems has become a highly complicated activity. During the data collection and analysis it was made clear that engineers need to manage and utilize huge amounts of information and while the complexity of the product has increased the architecture of the organization has not updated accordingly. The main proposition that this thesis elaborated in this regard, is to reinforce a system's thinking mindset and explore the product development challenges by using different perspectives such as analyzing the product decomposition from a different lenses than the conventional component-driven partitioning that has been employed historically. It emphasizes that maintaining static playbooks is no longer a sign of best practices, but instead, a sign of obsession to keep things are they were in the past. In order to execute correctly, the operational management should be attentive to the proposals that usually emerge from the teams that face the challenges every day. Modifying processes and procedures should occur regularly and basically should mimick the pace of disruption that characterizes today's digital transformation. The proposal also outlines that in order to get things done it is important to allow time and space for creativity to flourish, there will be always a tension between creativity and productivity and the suggestion exposed in this work represents an alternative in which a creative activity is extracted from the daily activities of some of the players and taken into a specific space.

5.2 Conclusions

The new business dynamic brought by the digital era is characterized by three main components:

- A shift in paradigms in almost all aspects of the business; talent management, complexity schemes for value creation and value capture.
- Unparalleled uncertainty. Knowing what is coming next is hard to anticipate

- The winners in this age are those who take the risk and perform bold actions.

However even in this rapid-changing environment and high levels of uncertainty is still possible to deliberatively *change the game*. But for doing so, organizations should exercise three main capabilities; adaptability, creativity and imagination.

Imagination is clue to understand future scenarios and should be practiced deliberatively. Organizations should invest and nurture it as part of organizations culture. Moreover should be seen as a dedicated activity and not as something that enhances daily tasks. Imagination is the only weapon corporations have to *risk safely* and act when there is still time and resources. If well exercised, it will provide the vision of the future of the *game*.

The next step is to be creative and act with what exist and add what needs to added. With enough creativity it is possible to rearrange ordinary resources and take them to do extraordinary actions which are the result of a superior level of integration rather than the collection of the best resources available. Understanding and deciphering the best way to execute and play demands high levels of creativity and the latter is facilitated when multiple persons participate. Diversity spurs creative solutions but requires people engagement. Thus, to engage them it is vital to communicate the vision as bold as it is; *changing the gam*e, and provide an environment where all ideas are welcome. It is unusual that someone refuses to participate in an endeavor that is meant to *change the game* but if that happens then it is very likely that the vision was poorly communicated.

Finally, adapting the organization and the strategies to *change the game* requires good experimentation within a punishment-free environment. It is important to keep in mind that every trial will deliver value as long as the organization is willing to learn from them. However it is still possible to experiment multiple times and learn nothing. It is not about just experimenting; every trial should be well planned and well executed.

5.3 Recommendations

The designed predictive-adaptation was crafted by studying current status of Ford's Product Development Organization regarding the development of in-vehicle features. Hence, it is a feasible option that in order to succeed requires certain elements that I recommend here:

The proposal considers the evolution of the resources, and in this context it is important to identify the right people to take over these actions. Given that the proposed role for the feature owner assumes a good understanding and management of modeling artifacts at different layers, I recommend selecting young people to work in this position. A young person usually is more willing to learn new competencies especially when the new knowledge involves a challenge.

I suggest that the transition to implement the model-centric development of in-vehicle features to start with those features that are under development right now and then focusing on those ones that create the more significant experiences.

In order to promote a rapid adoption of this proposal, I suggest that features that currently have the major complexity to be addressed first. I consider that showing the value added in those features will create a better impact in managerial levels that could resonate and help for a faster spread.

In this new business model (platform-based) what Ford wants is to continue being an active player in the mobility business and that means seizing the opportunities of the entire eco-system which will be heavily focused in the added services which are software-intensive. For this reason the organization should consider hiring additional resources dedicated to software development in order to explore the option of developing the software in house and only asking the suppliers for the hardware platform of the components.

If latter scenario occurs, and Ford goes for a software in-house development a plausible possibility is that Automotive ECU suppliers will not be willing to resign to its current position, where they make a lot of their profits by developing the software to automakers and they could even stop doing business with Ford. In order to be ready for such scenario, I recommend to start the development of new ECU architectures where the hardware allows the allocation of software that is primarily executed in the cloud and that just communicate with the vehicle for reading sensors inputs and commanding control actions.

I recommend following up the business of consumer robotics, because it is very likely that in the future, important applications can be derived by pairing the actions of autonomous vehicles with robots, especially in the caring of elder people. I suggest dedicating special a special team to study plausible synergies between automobiles and robots.

As the autonomous driving approaches the business dynamics in mobility services will be more sharply defined. However another area that should be monitored is the development of wearables. I recommend to study possibilities around the use of wearables in autonomous transportation.

5.4 Further study

This work has studied the disruptive adaptability of organizations with a focus on product development organizations and with the perspective of changing the game. The proposal was addressed from the perspective of a new business model that an organization has decided to pursue. However there are other perspectives that can be used to generate a predictive-based implementation of strategy.

One interesting perspective that can be further studied is the **imagination of the failure of the strategy**. The initial research question would be; *how does the management of the organization early detect that a disrupted-adaptation is failing?*

In the work that I developed in this thesis, I elaborated the successful future scenario, one where Ford changes the game stunningly. I pre-visualized how the success in the future of mobility business looks like and then I designed a proposal for adapting to that scenario. Something that could also be added to this work is imagining the failure of the strategy. Create a narrative of how the wrong execution of strategy is, and especially, what the signs that accompany it are. This approach is about being able to develop early indicators that will announce that something is not being executed correctly and with this information the organization would be in the right position to adjust in real time.

Another interesting study for further development would be about investigating the right adaptation of the talent management and retention needed in the digital era. During the investigation I was able to find information that reveals that the new generations are not being attracted by the automotive industries. In general, the new generations are not attracted by the "old style" industrial companies that have shaped the technology businesses over the last century. Instead, young professionals and Science Technology Engineering and Math (STEM) students are inclined and motivated to engage in "startup kind" companies that certainly are open to new ways of collaboration and compensation that long-lived companies do not offer. An initial research question could be; how should long-lived companies manage talent in order to attract the new generations of STEM students?

Definitely the adaptability of organizations is a matter that will become of bigger interest as the digital disruption progresses and I have no doubt that there is still much to be said in this topic.

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