Automotive Telematics: Colliding Clockspeeds and Product Architecture Strategy

by

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Rachel, I dedicate this thesis to you.

Biography

Nathan Everett has 8 years of work experience in automotive engineering at Ford Motor Company. His current assignment finds him in the Vehicle Integration activity, with responsibility for future Econoline vehicle programs. Previous assignments include Automatic Transmission Systems Engineer and Powertrain Attributes Engineering. During his career at Ford, Mr. Everett has earned two patents, one for the "Elastically Latched and Staked Assembly in a Kinematic Arrangement of an Automatic Transmission," and the second for a "Multi-functional Tailgate for Truck-like Vehicles."

Prior to his career at Ford, Mr. Everett worked as an undergraduate research assistant at the Field Robotics Center for three years while completing his bachelor's in mechanical engineering at Carnegie Mellon University. In addition to his work on four prototype field robotic systems, Mr. Everett co-authored two papers, "NEPTUNE: Aboveground Storage-Tank Inspection Robot System," and "BOA: Pipe Asbestos Insulation Removal Robot System."

Abstract

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Automotive telematics encompasses a wide range of meanings, but generally refers to marrying the vehicle with information and entertainment technologies such as GPS for navigation and tracking, wireless technologies to connect peripheral devices such as cell phones and PDAs to the car, and installation of video systems to enable gaming, video, etc. This research examines the challenges introduced as a result of integrating fast and slow clockspeed systems and subsystems with automotive telematics. The development time for the automobile runs 3-5 years, while consumer electronics introduce new designs every 6-12 months. In order to introduce telematics products and services in the vehicle at a rate the consumer demands, this work introduced a modularity rule; design modularity along the clockspeed boundary.

Once the modularity is in place along the clockspeed boundary, standards must be established in order to fully allow the fast clockspeed systems and subsystems to be integrated, at the faster clockspeed pace, within the slow clockspeed vehicle platform. In principle, the standards should be designed such that if the faster clockspeed system or subsystem meets the standard, it by definition satisfies the verification and validation requirements of the vehicle itself. With both modularity and standards in place at the clockspeed boundary, telematics products and services can be introduced at a pace appropriate for consumer electronic product demand.

In the case of telematics, the regulatory environment is set to heavily influence the playing field. Concerns over both driver distraction and the protection of privacy rights have led to a number of legislative activities that could restrict telematics capability, or in come cases, require it. Companies that are involved in the telematics arena need to proactively impact the regulatory process in order to shape the value chain in their favor.

Firms must holistically design and manage their product architecture, process, and supply chain and in light of standards and the regulatory environment. Individual strategies require entrants to decide how open or closed to make their architectures and standards, necessitating a fine balance between proprietary profit leverage, commoditization, and customer acceptance. This work asserts that each OEM must, at least initially, implement controlled standards at the clockspeed boundaries. Firms must holistically develop a telematics strategy that considers how regulation and standards will drive product architecture decisions, how firms can influence regulation and standards to their advantage, and they must understand that the dynamic interaction of architecture, supply chain, standards, and regulation together determine who realizes sustainable competitive advantage.

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Chapter 1: Introduction

Through the decade of the 1990's, consumer electronics became increasingly integrated into people's lives, in the form of computers, cell phones, pagers, and personal digital assistants. With this advent of instantly available communication and information came an unprecedented productivity boom in both business and personal pursuits. Rather than allowing for more leisure time, this increased productivity has placed ever-growing demands on people do to more in the time they do have. In response to these increased demands, the use of these electronics while driving or sitting in traffic has ballooned. Automakers recognize the potential to integrate these consumer electronics products and services with the vehicle, and are working to determine a winning strategy to leverage profits. This work examines the challenges facing the effort to bring these products and services, commonly referred to as telematics, to market in the automobile.

1.1 Motivation

Automotive telematics encompasses a wide range of meanings, but generally refers to marrying the vehicle with information and entertainment technologies such as GPS for navigation and tracking, wireless technologies to connect peripheral devices such as cell phones and PDAs to the car, and installation of video systems to enable gaming, video, etc. During the height of the internet bubble of the late 1990's, automakers and other business entities hailed telematics as the next cash cow for the industry, and launched companies and subsidiaries to reap the rewards. Some entities, such as ATX, began on their own, while others, such as GM's OnStar and Ford's Wingcast, sprung out as offshoots of the OEMs. When the Internet bubble burst, reality set in and tempered the enthusiasm and wild profit projections that had fueled development to that point. Automakers and other entrants were left with a sense that there is profit to be made, but saddled with clouded uncertainty as to what customers are willing to buy.

As the industry moves forward to try and integrate these electronics products and services with the vehicle, they face lingering questions of how to concurrently design product and supply chain architectures to provide sustainable competitive advantage. Additionally, increasing uncertainty surrounding whether standards should be set, and if so, how to set them, along with pending regulatory action to address driver distraction concerns and privacy rights continue to cloud the road to profitability. This thesis begins to offer guidance for the engineering manager navigating this fog.

1.2 Telematics Overview

As stated previously, telematics has a number of meanings. Roland Berger states that telematics "includes all technologies providing two-way data and voice communication between the vehicle and external sources,"[1] while USAToday defines telematics as "electronics and communications that provide guidance and information to drivers."[2] Car and Driver defined telematics as "a suitably techie-sounding word that describes the hard-, firm-, and software that permits communication between a car and driver and the rest of the universe."[3] While the definitions of telematics vary depending upon whom one asks, several key pieces of a telematics system are common. First, telematics allows the driver to maintain some contact with the outside world, typically through some sort of wireless data transfer technology. Second, a telematics system includes several necessary components: a user interface, software applications, hardware capability, and a means to provide wireless connectivity. The ways in

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[1] From "Telematics: How to Hit a Moving Target," Roland Berger Strategy Consultants, November 2001, page 12

[2] From "Automakers Develop Voluntary tech Safety Standards," USAToday.com, April 26, 2002

[3] From "Can You Hear Me Now," by Fred M.H. Gregory, caranddriver.com, September 2002

which these components are used in a telematics application vary depending on the aim of the system. As will be discussed in section 1.4 Focus and Scope, the intent of this work is not to define telematics in great depth, nor to provide a great deal of detail regarding the generic products and services in the marketplace. A number of good sources provide this information, and for convenience purposes the author has chosen to present two figures from a Roland Berger presentation to complete this background discussion. Figure 1: General Telematics Schematic Definition graphically depicts Roland Berger's definition of telematics, and Figure 2: Telematics Services Summary lays out a variety of telematics services.

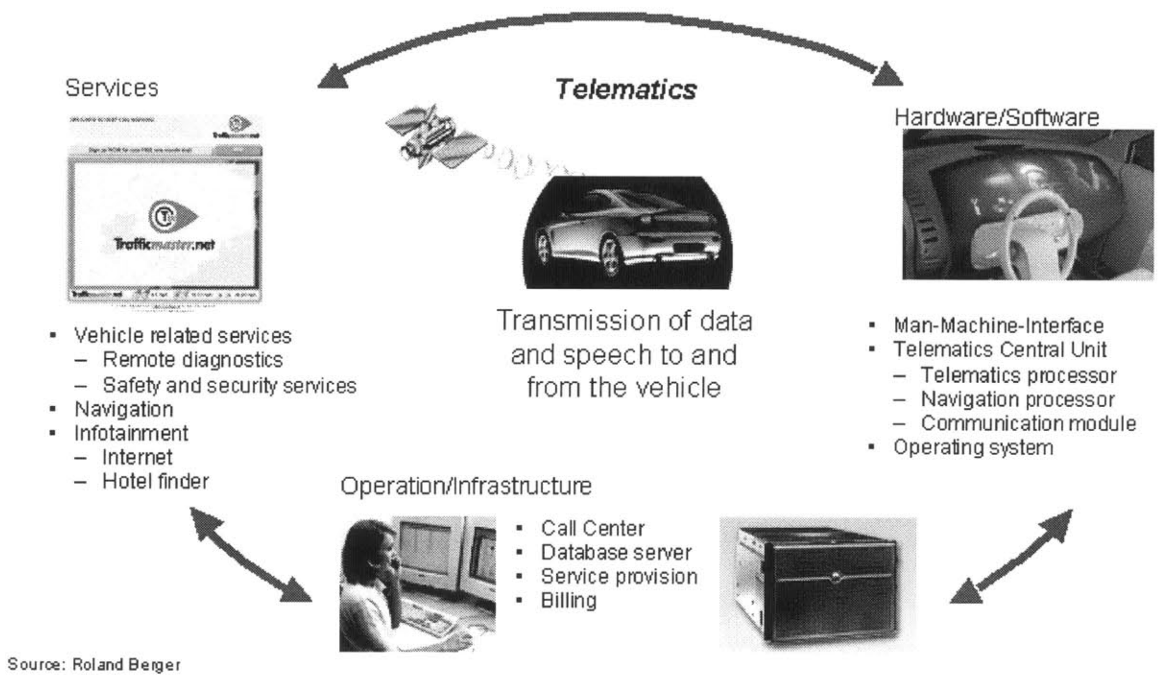

Figure 1: General Telematics Schematic Definition[4]

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[4] From "Telematics: Facts, Opportunities, and Uncertainties," Roland Berger, July 26, 2002

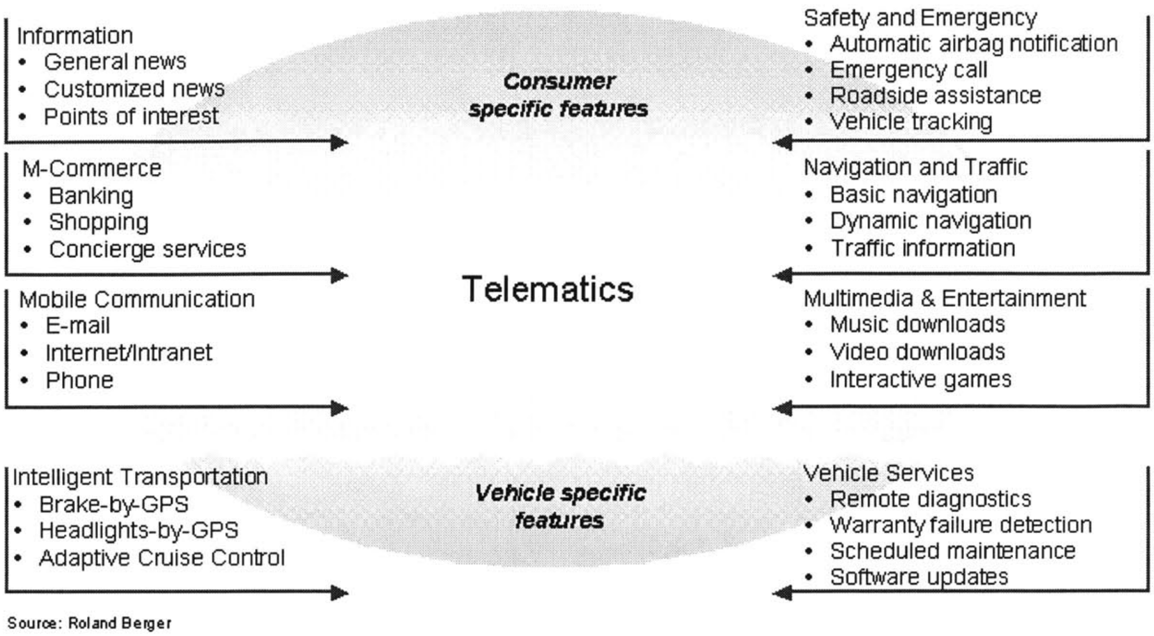

Figure 2: Telematics Services Summary[5]

For the purpose of this work, the author has chosen to define telematics as *the marrying of the vehicle with information and entertainment technologies such as GPS for navigation and tracking, wireless technologies to connect peripheral devices such as cell phones and PDAs to the car, and installation of video systems to enable in-vehicle gaming and video entertainment.* This definition expands on previously cited versions in that it specifically includes consumer electronic system elements, such as video capability, that do not necessarily require or involve an interaction with the world outside of the vehicle. The reason for expanding the definition in this manner will become apparent as the scope of the work is defined.

Just as the definition of telematics varies widely, so do the projections of the revenue potential. Not only do estimates vary from one source to another, but these revenue estimates from the

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[5] From "Telematics: Facts, Opportunities, and Uncertainties," Roland Berger, July 26, 2002

same source have also been reduced dramatically in a short period of time as the tech bust has resulted in different expectations for customer demand, and increased data regarding customer adoption has become available from sources such as OnStar and ATX. In 2000, UBS Warburg was projecting worldwide end user telematics revenues of $49 billion in 2010. By November of 2001, Roland Berger referenced UBS Warburg's numbers in its lowered estimates for the market. In just a year, an estimate of $49 billion (in 2010) by one firm was reduced to $24.3 billion (in 2010) by another.[6] More directly, The McKinsey quarterly projected likely revenues (in 2010) of $40 billion in a 2001 article[7], which was revised downward just a year later to likely revenues (in 2010) ranging from $15-$20 billion.[8] With such uncertainty in the marketplace, companies offering telematics products and services are hesitant to become too committed, but still have a sense that revenue potential exists and are not backing away from telematics.

1.3 Market Uncertainty

One of the most often cited roadblocks for wide adoption of telematics is the uncertainty surrounding what customers are willing to pay for. To some extent, OnStar has demonstrated that there is a demand for safety and security features, such as remote vehicle unlocking and automatic crash or airbag deployment notification. This does come with a bit of a caveat, since OnStar's offering on General Motors' vehicles is free for the first year, and OnStar does not publicly release subscription renewal data following that first year. OnStar customers have a choice to renew at one of several service levels, with the basic level providing basic safety and security features, while the highest level offers access to personal concierge services. Even though OnStar does publicly release the total number of subscribers, it does not detail what

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[6] From "Telematics: How to Hit a Moving Target," Roland Berger, November 2001, pp 20-21

[7] From "The Road Ahead for Telematics," The McKinsey Quarterly, 2001 Number 2, page 7

[8] From "A Road Map for Telematics," The McKinsey Quarterly, 2002 Number 2, page 102

level of service those customers are buying. Industry-wide speculation is that those customers that do renew predominantly elect to do so at the basic service, which is believed to be a loss scenario for OnStar.

This sense of uncertainty has indeed slowed the surge of telematics products and services to the market, but companies are proceeding cautiously nonetheless. It is the author's belief that in time the market equation will indeed net a profit, and that the companies that are best in place to lead or quickly move to the winning solution will be most successful. The question that then drives the rest of this work is what does it take for a company to be ready to lead the winning telematics strategy?

1.4 Focus and Scope

To research and study the market wants for potential telematics customers would be a substantial thesis in its own right, and a number of academic and consulting sources currently provide analysis on exactly that issue. This work does not suggest that understanding the market potential and needs for telematics is not necessary, merely that the value added by in-depth research from this author would be minimal. Given the author's background in automotive product development, a deeper question arose when peering down the road of telematics implementation: once the market needs, market size, and customer wants for telematics are understood, how does a company move to deliver those products and services in a manner that will capture the largest possible value?

The enormous capital investment requirements to design, manufacture, sell, and service an automobile have given rise to large organizations that shun risky decisions which might jeopardize that capital investment. Add the complex functional requirements that an automobile must deliver, and the high level of focus given to the safety of automobiles, and these organizations tend to move deliberately and thoughtfully. While this is a positive trait in the mind of anyone who trusts a vehicle for his or her daily transportation needs, it means that these organizations can find it difficult to rapidly shift course to implement new technologies as they arise.

So what is the big deal? New technologies are continually being introduced into vehicles every year. Why would telematics present any more of an implementation issue for automotive companies than past technologies have? It was during the exploration of this exact question that the focus and scope of this work drew its clarity. The fact is that telematics is different than past technologies in several key ways. First, it represents a union of two very different value chains; the automotive value chain and the telecommunications value chain. Entrants in each chain are accustomed to their way of doing business, and are also accustomed to dealing directly with the customers. In many cases, they already have established relationships with their customer bases that they don't want to jeopardize, or that the customers themselves want to maintain. Second, government intervention in the form of safety and other legislation is set to significantly impact potential telematics products and services. But the most fundamental issue that will make it difficult for automotive companies to manage telematics is that the rate of change of consumer electronics is much faster than the rate at which automakers re-design a vehicle. For this reason, this work expanded upon the traditional definitions of telematics to include other in-vehicle entertainment such as video game and DVD systems, which also develop at much faster rates than the vehicle. It is this disconnect in development speed that will relegate the unprepared OEM to the back of the pack once telematics takes off.

This work accepts the market uncertainty facing automotive telematics, and accepts the expectation that profit potential exists once the customer needs are understood. This work does not attempt to present ways in which to resolve that market uncertainty, but instead scopes itself as a framework with which to prepare to implement telematics when it takes off. It focuses on the fundamental issue of managing technologies from industries that evolve at different rates, suggests a modularity design rule to deal with those conflicting rates of evolution, discusses how to set standards at those modular boundaries, evaluates potential supply chain scenarios, presents an analysis of regulatory implications, and provides product architecture guidance. Finally, the work concludes with a chapter that summarizes current telematics offerings and analyzes them utilizing the framework presented in this work.

Chapter 2: Clockspeed Collision Analysis

While the market uncertainty is creating issues for automotive companies when it comes to introducing telematics products and services, a larger issue looms just over the horizon when these uncertainties become clearer and automotive companies move to implement telematics. The consumer electronics industry evolves at a much faster rate than does the automotive industry, and this conflict will make it very difficult for automakers and suppliers to implement customer demand for current telematics technology within the design and development processes developed for the automotive industry. This chapter describes the concept of clockspeed as a framework to understand the different rates at which industries evolve, discusses the issues associated when these industries collide along what is termed a clockspeed boundary, introduces a design rule for modularity along the clockspeed boundary to manage this conflict, and discusses two industry examples that demonstrate applications of this design rule.

2.1 Clockspeed

"In the fall of 1995, [Prof. Charles Fine at MIT] was four years into a seven-year research project on a challenging topic: the strategic impact of supply chain strategy on competitive advantage,"[9] and was frustrated with the inability to rapidly test his hypothesis because the industries that he was studying changed so slowly. He then read of Nobel prizes in medicine that had been awarded to three researchers "for their work on the process whereby embryos develop from a single cell into complex adults."[10] During the course of that work, the researchers spent years studying mutations in generations of fruit flies, "because their genetic structure is similar to that of humans, because hundreds of them can be kept in a small milk bottle, and because, despite

[9] Fine, Charles, "Clockspeed: Winning Industry Control in the Age of Temporary Advantage," p. 4.

[10] Fine, Charles, "Clockspeed: Winning Industry Control in the Age of Temporary Advantage," p. 3.

their genetic complexity, they evolve rapidly: they go from egghood to parenthood to death in under two weeks."[11] After reading of the Nobel work, Prof. Fine sought the business parallel to the fruit flies in medicine; could he study industries that evolved at faster rates than the ones he was studying in order to more quickly test his hypothesis? The answer turned out to be yes, and he "came to think of these rates as industry *clockspeeds*. Each industry evolve[s] at a different rate, depending in some way on its product clockspeed, process clockspeed, and organization clockspeed."[12] Figure 3: Measuring Clockspeed – Sample Industries lists clockspeeds of various industries, as of the book's 1998 publication date.

In the case of telematics, this notion of clockspeed plays a large role in the difficulty that automakers face when it comes to implementing telematics products and services. On the one hand, the technologies that make up telematics hardware and software evolve at a high rate, with clockspeeds on the order of 6-12 months, while on the other hand, the vehicle platform itself has a much slower clockspeed, evolving every 3-5 years (Note: in the time since the publication of clockspeed in 1998, the automotive product clockspeed has sped up from the 4-6 years shown in Figure 3: Measuring Clockspeed – Sample Industries). Given the ubiquitous use of consumer electronics such as cell phones, pagers, and PDAs, customers have an understanding of the clockspeed of these technologies – they know how quickly they become obsolete, or how quickly something better comes along. While this is not the first time automakers have implemented technologies with faster clockspeeds than the vehicle (for example, the computer chips that comprise engine control modules evolve much faster than the vehicle, but customers aren't directly aware of this and do not experience unsatisfactory

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[11] Fine, Charles, "Clockspeed: Winning Industry Control in the Age of Temporary Advantage," p. 3.

[12] Fine, Charles, "Clockspeed: Winning Industry Control in the Age of Temporary Advantage," p. 6.

performance if the latest chip is not in a vehicle), it is the first time that customers will be keenly aware of it, and will make buying decisions on the ability to have the latest technology.

Industry	Product Tech Clockspeed	Process Tech Clockspeed	Organization Clockspeed
FAST CLOCKSPEED INDUSTRIES			
Personal computers	< 6 months	2-4 years	2-4 years
Computer-aided software engineering	6 months	2-4 years	2-4 years
Toys and games	< one year	5-15 years	5-15 years
Athletic Footwear	< one year	5-15 years	5-15 years
Semiconductors	1-2 years	2-3 years	3-10 years
Cosmetics	2-3 years	5-10 years	10-20 years
MEDIUM CLOCKSPEED INDUSTRIES			
Bicycles	4-6 years	10-15 years	20-25 years
Automobiles	4-6 years	4-6 years	10-15 years
Computer operating systems	5-10 years	5-10 years	5-10 years
Agriculture	3-8 years	5-10 years	8-10 years
Fast food	3-8 years	25-50 years	5-25 years
Beer brewing	4-6 years	400 years	2-3 years
Airlines	5-7 years	25 years (hardware) 2-3 years (software	< 5 years
Machine tools	6-10 years	6-10 years	10-15 years
Pharmaceuticals	7-15 years	10-20 years	5-10 years
SLOW CLOCKSPEED INDUSTRIES			
Aircraft (commercial)	10-20 years	5-30 years	20-30 years
Tobacco	1-2 years	20-30 years	20-30 years
Steel	20-40 years	10-20 years	50-100 years
Aircraft (military)	20-30 years	5-30 years	2-3 years
Shipbuilding	25-35 years	5-30 years	10-30 years
Petrochemicals	10-20 years	20-40 years	20-40 years
Paper	10-20 years	20-40 years	20-40 years
Electricity	100 years	25-50 years	50-75 years
Diamond mining	Centuries	20-30 years	50-100 years

Figure 3: Measuring Clockspeed – Sample Industries[13]

[13] Fine, Charles, "Clockspeed: Winning Industry Control in the Age of Temporary Advantage," p. 239.

2.2 Clockspeed Collision Boundary

When two industries that evolve at different clockspeeds come together, it creates a boundary that the author terms a *clockspeed collision boundary*. In its November 2001 report, Roland Berger subtly noted, "in ever-shorter innovation cycles, existing and new technologies are converging."[14] Car and Driver recognized this issue in a September 2002 article – "Then there's the techno-lag. Lead times in the digital world are measured in months, whereas it takes years to develop a car."[15] Both of these quotes hinge on the concept of clockspeed, and recognize that clockspeed conflicts will present issues to the industry as it moves to implement telematics.

Okay, so consumer electronics products and services have a faster clockspeed than the vehicle, and therefore a clockspeed collision boundary exists – why will this be such a difficult problem for the industry? In the case of telematics, the difficulty arises due to the integral nature of the typical automotive product development process. As shown in Figure 4: Generic Product Development Process, a typical product development process involves sequential phases of definition, design, development, and manufacture. As part of the project management processes used to execute vehicle programs, gateways or milestones are defined such that to move from one phase to the next, all aspects of the system must achieve a common level of readiness at the same time. Within phases of the process, there may be iterations in a number of activities to address shortfalls along the way, but when it comes time to move to the next phase, all systems and subsystems do so at the same time. Were the process modular in nature, systems and subsystems would individually meet the respective gate or milestone requirements when necessary to meet the ultimate timing for the program.

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[14] From "Telematics: How to Hit a Moving Target," Roland Berger, November 2001, p 12.

[15] From "Can You Hear Me Now," by Fred M.H. Gregory, caranddriver.com, September 2002.

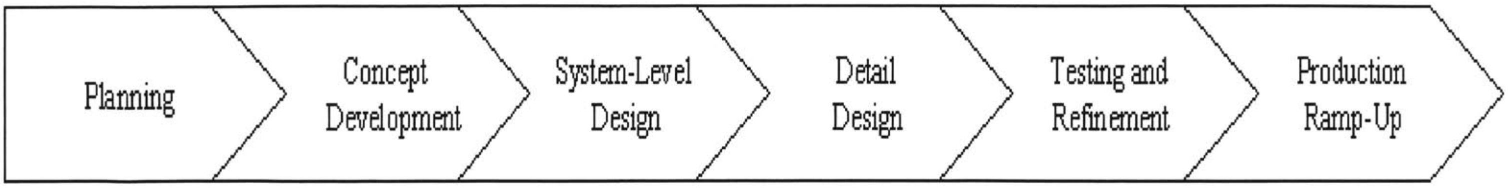

Figure 4: Generic Product Development Process[16]

Carrying the integral situation a step further, one needs to focus on the testing and refinement phases of the generic product development process. An automobile is required to meet a host of complex emergent properties, including safety, performance, weight, cost, fuel economy, manufacturability, reliability, etc. Given the complex nature of these emergent property requirements, and the number of interactions between them, automakers must perform extensive verification and validation to ensure that the system requirements are met. In the integral product development process, every system and subsystem remains in this phase until the last one meets its requirements to proceed through the gate or milestone. In actuality, it does not take much time to design and build a vehicle; it is this extensive verification and validation process that comprises most of the development time and drives the clockspeed of the vehicle.

As a result, the automaker faces a dilemma. If one holds the faster clockspeed systems to the verification and validation timeline of the vehicle, one cannot continually bring these products to market when the customer demands them. On the other hand, if the automaker redesigns a vehicle every 6-12 months to keep pace with rate of change of consumer electronics, either its costs would soar to non-viable levels, or it would not be able to achieve some or all of the

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[16] Ulrich, Karl, and Eppinger, Steven, Product Design and Development, second edition, 2000, p 9.

system emergent property requirements. Neither of these two scenarios is acceptable, so the industry must seek a different strategy to manage this clockspeed collision boundary.

2.3 Clockspeed Boundary Modularity

It is clear that the industry will have difficulty implementing telematics due to the clockspeed collision boundary presented by the number of technologies that are evolving at different speeds. With the current integral nature of typical automotive product development processes, and the length of time required to verify and validate the most complex system emergent properties, what strategy should one employ to be able to implement telematics products and services at its faster clockspeed while delivering the vehicle emergent properties within a profitable business scenario? The answer is a new concept for product modularity: ***design product modularity along the clockspeed boundaries with appropriate standards.*** In this context, what is meant by modularity is the decoupling of functions. So said another way, one must decouple the functions of the system at the clockspeed collision boundary with appropriate standards at that boundary. The discussion as to what constitutes and appropriate standard, and a methodology for designing appropriate standards is presented in chapter three.

Both entrants stand to benefit from product modularity at the clockspeed boundary. For the slower clockspeed entrant, it provides a stable platform on which its profit and business models are based. In the case of the faster clockspeed entrant, this supports the need to be able to introduce products fast enough to keep pace with market demands for new designs at an affordable cost.

2.4 Clockspeed Boundary Modularity Models: The PC and Video Game Consoles

In the previous section, the modularity concept to design product modularity along the clockspeed boundaries with appropriate standards was introduced. But the question is, is this just a nice academic concept, or does it work in the real world? The answer is that successful examples of designed modularity along clockspeed boundaries with appropriate standards are numerous. This work discusses two of those examples, the personal computer (PC), and the video game console, such as Nintendo Gamecube, Microsoft Xbox, or Sony Playstation. Both of these classes of products have implemented product modularity along clockspeed boundaries, and have been chosen because they implement standards differently.

2.4.1 The Personal Computer (PC)

When IBM designed the first desktop personal computers in the late 1970's in response to Apple's foray into this new market, it opted for a modular architecture. Prior to that time, IBM, along with the other large computer manufacturers, were large, vertically integrated companies that designed and built every piece of their highly integral computer systems, from the electronics to the operating systems. This burden was viewed as too cumbersome to maintain with the addition of a new product line, and the PC architecture was modularized so that pieces of the system could be outsourced. Without intending to do so, IBM established those modular interfaces at the clockspeed boundaries, and established open standards at those boundaries. Even today, operating systems evolve at different rates than keyboards, which evolve at different rates than network card, which evolve at different rates than processors, which evolve at different rates than display devices, and so on and so forth. IBM chose to operate in the area it new best, as a computer system assembler and seller. Unfortunately for IBM, the operating systems and processors turned out to be the key drivers of PC performance and customer demand, two areas in which they were not active. Because they had defined open standards at those boundaries, they could not prevent others from selling those types of products to customers. While this is a negative outcome for IBM, it turned out to be an outstanding decision that drove the widespread success of the IBM PC. As part of that success, other entrants in the industry have reaped enormous profits.

Contrast this to the experience at Apple. In the early to mid 1980s, Apple was the leader in the PC market. Its architecture is fundamentally the same as an IBM PC in that it has a processor, an operating system, a shell, various disk drives, a mouse, a keyboard, a monitor, etc. However, while the Apple computers also implemented design modularity along the clockspeed boundaries, it did so with closed standards at those interfaces. While this initially was a successful strategy, the introduction of the PC with open standards eventually took over due to the benefits of network effects, which will be discussed in chapter three.

2.4.2 Video Game Consoles

While the IBM PC succeeded with open standards at the clockspeed boundaries, the video game consoles such as Sony's Playstation, Microsoft's Xbox, and the Nintendo Gamecube have succeeded with closed standards at the clockspeed boundaries. In particular, the clockspeed boundary studied here is the one between the game and the console itself. The consoles are redesigned every 2-3 years, but games for these consoles come out almost continuously. For example, many of today's popular sports video games are updated each year. With the modular architecture present at the clockspeed boundary, the game console makers do not need to verify and validate every new game as it is released. As long as the game is designed to the closed standards at that boundary, it will run on the system.

So what does it mean to have a closed standard at the clockspeed boundary in this case? It simply means that the interface specifications at the clockspeed boundary – the boundary between the game and the console – are proprietary creations of the console manufacturers. If an entrant wants to release a game for a particular system, it must contractually arrange with the console maker to get those specifications, and get permission to use them in the design of the game. It also means that a game designed to run on one manufacturer's system will not run on another manufacturer's system. If the standards at the clockspeed boundary were open as in the case of the IBM PC, then a game that runs on Playstation would also run on Nintendo Gamecube. In this case, what constitutes appropriate standards is different than in the case of the IBM PC.

The next chapter explores standards in more detail. It starts with a discussion on standards, explores the meaning of appropriateness of standards, and presents a methodology for designing standards. It also evaluates the leading standards effort to date in telematics.

Chapter 3: Standards

Standards impact every facet of our lives; often in ways we take for granted. In the U.S. for example, we have a standard electrical system, a standard plumbing system, a standard roadway system, standard widths for railroad tracks, and so on. But how do these things become standards, and who decides? Furthermore, why are some aspects of life standardized, and not all? And finally, how should standards be set in telematics? This chapter answers these questions by discussing standards in general, presenting a generic methodology to design standards along clockspeed collision boundaries, and evaluating the leading telematics standards effort to date.

3.1 Standards Summary and Appropriateness

Standards play a key role in our ability to function in every facet of our lives. Imagine trying to rent a movie if the VHS or DVD formats had not been standardized. Imagine trying to buy a light bulb that would screw into your bedroom lamp if the base of the bulb were not standardized, or that would turn on if the voltage to your house were different from your neighbors'. Imagine trying to safely drive from New York to Baltimore if every town had different sized roads, and none of those towns' laws required drivers traveling in the same direction to use the same side of the road. The result would be chaos. In the case of the light bulbs, one would never be sure they could generate light with the purchase of a lamp. More seriously, one could not reasonably expect to survive the trip to Baltimore if standards didn't exist for traffic.

The main property of standards is that they define a generally accepted common mode where they are applied. For example, a compatibility standard defines a common interface or physical connectivity property, as in the case of the light bulbs and electricity. A safety standard defines a common set of rules one must operate within, as in the case of traffic direction standards.

There are even standards that exist to define the quality of products or experiences. In all of these examples, they key is the element of recognized commonality. Those who use products or services that apply those standards know what to expect, and those who produce those products and deliver those services know what's required in order for them to work.

Standards can be set in a number of ways, but they generally fall into one of two main categories: legislated standards and negotiated standards. The United States has a number of laws ranging from criminal law to the safety standards that automakers must meet. These legislated standards begin as complaints that constituents pass on to their senators and representatives in the U.S. Congress. If enough people complain about a concern, or if a powerful enough special interest group pushes a concern, then legislation gets introduced as a bill. Depending on the type of legislation, the bills get debated in the House and Senate, in committee, or in an agency empowered to enact legislation in a specific area. A legislative vote then determines whether or not the bill is signed into law. A key example of an empowered agency that affects the auto industry is the National Highway Traffic Safety Administration (NHTSA), which passes the safety laws that govern vehicle safety in addition to other lesser responsibilities. NHTSA and the regulatory environment surrounding telematics are discussed in greater detail in chapter 5.

The second way in which standards can be set is through agreement. A majority of the standards in effect today fall into this category. The examples of standards setting along the clockspeed collision boundaries for the PC and video game consoles presented in the previous chapter are standards that were established by agreement. In the case of the PC, IBM decided that anyone could see and use the standard it designed, while the video game console makers will only allow their standards to be used under specific circumstances. This highlights another important property of standards; they can be either open or closed. Open standards are standards that are publicly available, and that one can utilize without any restrictions. Legislated standards are for the most part open, although there are examples of legislated standards that have some properties of being closed. A prime example in the auto industry is a driver's license, which is required in order to drive, but you must pay in order to get one. A closed standard is one that nobody can see or apply except for the one who wrote the standard. Most standards today fall in between, having some properties of a closed standard, and some properties of an open standard. The discussion as to appropriateness of standards revolves around the issue of how open or closed to make a standard.

So what makes standards so powerful and effective? Everyone can easily see the benefits from having a standard home video format, a standard light bulb, and standard traffic laws, but there is an underlying behavior principle that is the key to standards. Standards deliver value through this principle, known as indirect network affects. These network effects add value through the complementary goods and services they enable. For example, a VCR is no good without a VHS tape, just as the VHS tape and VCR are no good without movies or programs to buy, rent, or record. These different products work together to deliver the value of the system. By having these different pieces of the puzzle interact through standards, they are of far more value than any would be alone.

The dynamics of network affects are show in Figure 5: Network Effects Reinforcing Loop. When a product such as a DVD player first starts out, people are hesitant to buy the technology until the number of complements, in this case movies on DVD, reaches a point where they can get the movies they want. The companies that produce movies are therefore initially hesitant to produce movies on DVD, since not many people own the players, and will therefore not buy many movies. The same argument applies to a video rental company; if not many people own a DVD player, then not many people will pay to rent DVDs. At some point in time, a successful technology delivers something that customers desire (in the case of DVD, improved picture quality and sound), and they begin buying in larger numbers. This larger installed base then motivates companies like studios and rental shops in the case of DVD to make more DVDs available. The point at which the behavior switches from people waiting to see what will happen to where everyone gets in the game is known as the tipping point. The bottom line with the benefit of network effects is that the larger the number of users adopting the standard, the more value there is associated with belonging to the standard.

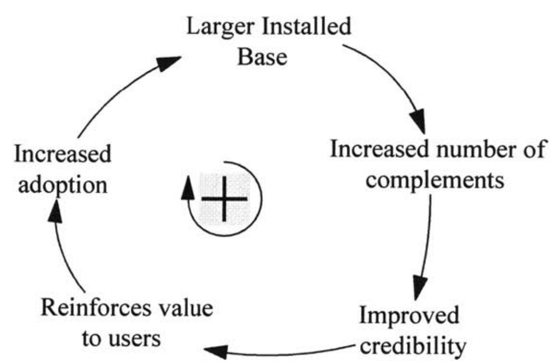

Figure 5: Network Effects Reinforcing Loop

This behavior is heavily influenced by the openness of the standards. If it is too difficult or costly to apply a standard, or if a company limits the extent to which its standard can be used, the number of complements will be limited. In the discussion of Apple vs. IBM for PCs, we saw that when a similar technology entered the marketplace with open standards, the market demand exploded and it surpassed the technology that used the closed standard. In the case of the video game market, if one could make a game console that would play games designed for any console system, then that company would quickly dominate the market since customers could play any game and only have to buy one system. However, since the game console makers each own their standards as intellectual property, it is not likely that someone could get permission to make such a unit.

Now that the key properties of standards have been presented, these concepts need to be applied to the design modularity rule presented in the previous chapter: design modularity along the clockspeed boundary *with appropriate standards*. As mentioned earlier, the definition of appropriate standards hinges around how open or closed one makes a standard. ***This work asserts that automakers should pursue the model of the video game console makers and work towards individual restricted standards.*** If a telematics standard is established within one automaker, and that standard is held by the automaker in much the same way as a video game console manufacturer controls its standards, then the automaker maintains leverage and control. But there are two key risks with this approach. First, the limited market size associated with the restricted network effects may not be large enough to generate enough revenue for the automaker. Second, and more important, if a group of automakers band together and decide to release telematics products and services on an open standard, then the automaker with the closed standard is likely to be overrun as was Apple by the IBM PC. Ultimately, the network effects will decide whether or not one can make a profit with closed standards, but one should try to do so if possible.

3.2 Standards Methodology for the Clockspeed Collision Boundary

"Upgradeability of installed devices and development of common standards to enable a plug-and-play market for telematics devices will be preconditions for the further development of the market."[17] This work does not agree with Roland Berger's assertion that common (open) standards are needed for telematics; automakers should at first develop controlled standard

[17] From "Telematics: How to Hit a Moving Target," Roland Berger, November 2001, page 9

systems in a way that the market supports. But the question still remains, now that we know we need appropriate standards at the clockspeed boundary, how do we design them? As stated in chapter 2, the reason the clockspeed collision boundary presents such a problem for automakers is due to the integral nature of the product development process, with the clockspeed heavily dictated by the verification and validation requirements of those product development processes. In order to assure that the complex emergent properties of the vehicle are achieved, each vehicle must undergo a number of iterative tests to verify achievement of the objectives. Given this lengthy process that often requires having all of the representative hardware present for each test, how can one hope to verify and validate the faster clockspeed telematics at it's own pace? The answer is simple: ***design the standards such that if the faster clockspeed subsystem or system meets the requirements of the standard, then it by definition meets the verification and validation requirements of the slower clockspeed system.*** By applying this methodology when setting standards, OEMs can continue to design vehicles at the vehicle clockspeed, and then just "drop in" faster clockspeed telematics systems and components as they evolve at their own pace.

One thing to realize here is that this cannot be a static standard! OEMs are continually improving and adjusting their product development processes to reduce their vehicle development clockspeed and to increase the quality of the process output. As the processes evolve over time, and as the verification and validation tools and requirements evolve over time, so must the standard.

Finally, while similar in nature, OEMs use different product development processes. Some are more modular than others, and each one moves at a slightly different rate, but they are indeed different. For this reason, any standard that could apply across these differences would not be able to implement the design modularity rule along the clockspeed boundary. This is yet another reason to implement controlled standards unique to each automaker. The next section describes the leading telematics standards effort to date, spearheaded by AMI-C.

3.3 Automotive Multimedia Interface Collaboration (AMI-C)

To date, the most widely recognized standards effort for telematics has been the Automotive Multimedia Interface Collaboration, or AMI-C. AMI-C is an organization currently consisting of 8 automotive manufacturers that have organized to set interface standards in the multimedia and telematics areas. Their goal is to establish a standards network that will allow interoperable devices and common applications to exist on a common in-vehicle network. As a testament to the difficulties faced by automotive manufacturers as they move to incorporate telematics in their vehicles, AMI-C recognizes that "the automotive industry desperately needs a common mobile information and entertainment architecture."[18] But more importantly, though it's stated objective to "reduce obsolescence of vehicle electronic systems by aligning development and *vehicle insertion cycle time* with the consumer electronic industry, and by providing for upgrade capability,"[19] AMI-C recognizes the presence of the clockspeed collision boundary that automakers face when trying to incorporate telematics. So the question is, does AMI-C's proposed standards solution apply the rule of modularity along the clockspeed boundary?

3.4 AMI-C Standards Architecture

As shown in Figure 6: AMI-C Architecture Representative Block Diagram, the AMI-C standards architecture represents a layer between the OEM proprietary vehicle network and the customer interface. In addition, the standard provides for a common message set so that necessary information from the vehicle proprietary network is provided to the AMI-C compliant network. For example, a navigation system located on the AMI-C compliant network would get a vehicle

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[18] From http://www.ami-c.org/, November 11, 2002

[19] From http://www.ami-c.org/ Objectives, November 11, 2002

speed common message delivered to it from the proprietary vehicle network according to the common message set specification. It could then take position data from the GPS system, also located on the AMI-C compliant network, to calculate estimated time remaining in a trip. In this standards architecture, we see a mix of modularity defined by clockspeed boundary, and a mix defined by organizational boundary.

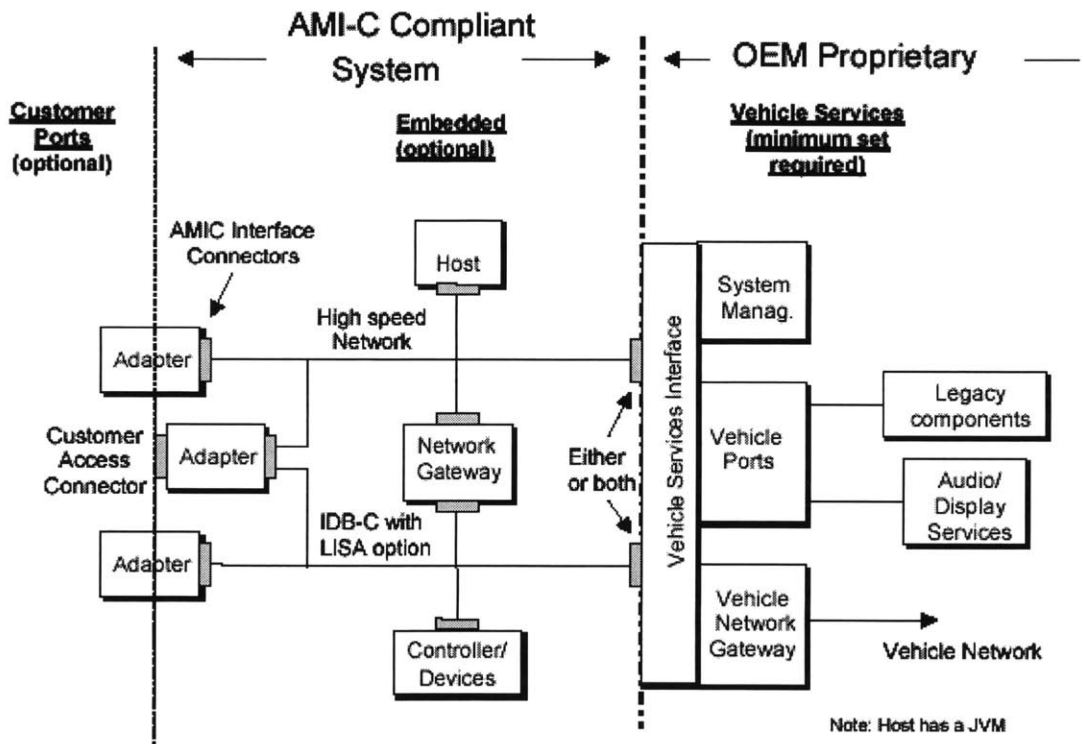

Figure 6: AMI-C Architecture Representative Block Diagram[20]

For example, the audio/display services on the OEM proprietary network may operate at the same clockspeed as one or more of the devices on the AMI-C compliant system. Rather than provide for modularity along a clockspeed boundary in this instance, the standards architecture provides for modularity along organizational boundaries (i.e., separating similar clockspeed

[20] From AMI-C SPEC 1002-0-0, Release 1, 2001, p. 2

components according to who manufactures them). While this seems contradictory at first to the design modularity rule along clockspeed boundaries, and to AMI-C's own goal to "adopt open standards and specifications for information interfaces within the vehicle and between the vehicle and the outside world."[21], it shows that automakers are not willing to give up total control over the path of telematics.

It seems that confusion exists even within AMI-C as to how far to go towards open standards, and this work asserts that an open standard for telematics is not feasible. First, the product development processes differ enough among the automakers that one standard would not complement everyone's process. But more importantly, this idea of control over the vehicle and the profits are preventing automakers from supporting a fully open standard from AMI-C. While the "gut reaction" may be a fear of losing control, there is another key reason for each automaker to maintain individual control over its telematics standard. To get a deeper understanding as to what that is, we must explore the supply chain scenarios associated with telematics.

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[21] From http://www.ami-c.org/ Objectives, November 17, 2002

Chapter 4: Supply Chain Analysis

As stated at the beginning of this work, telematics represents an intersection of two very different value chains; the automotive value chain and the telecommunications value chain. For the purpose of exploring the appropriateness of standards, and to support the argument that an automaker should maintain individual controlled standards for telematics, this chapter will explore an important aspect of the value chain - the supply chain.

How important is it to understand the supply chain impacts with telematics? According to strategy and market research consultant Paul Hansen, who publishes The Hansen Report on Automotive Electronics, "those likely to profit most from telematics will be companies that effectively control the product chain."[22] This chapter explores the potential supply chain implications associated with the standards choices facing telematics. First, the work explores the traditional automotive supply chain, then explores a potential supply chain outcome in the context of open standards, and finally presents the potential hybrid supply chain implications associated with some level of standards closure.

4.1 Traditional Automotive Supply Chain

As shown in Figure 2, the traditional automotive supply chain involves suppliers selling products and services to the OEM, who in turn integrates those pieces into the vehicle, which is then sold to customers.

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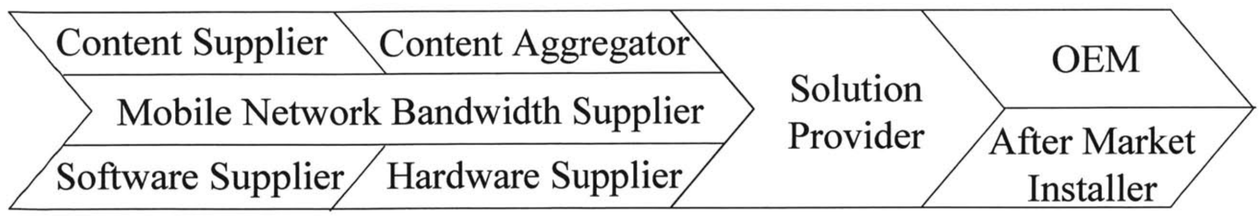
[22] From "Mobile Electronics Compete with OEMs," Automotive Industries, February 2002, page 20



* Adapted from The McKinsey Quarterly, 2001, Number 2, p. 8

Figure 7: Traditional Automotive Supply Chain

In this structure, the design and purchasing relationship involves individual requirements agreements between the top tier suppliers and the OEM, thus allowing the OEM to retain a large amount of control over the relationship with the end customer. For example, a tier-3 supplier may provide a circuit board to a tier-2 supplier, who in turn integrates that board into a telematics control module (TCM) that the tier-2 then provides to a tier-1 solution provider. The solution provider would then integrate the TCM with other hardware, software, and service products and provide the package to the OEM. With this arrangement, neither the tier-1 nor tier-2 supplier has a relationship with the end customer; the OEM controls the relationship directly. This traditional structure has held since the beginning of Henry Ford's vertically vision of an automaker, but with telematics, the customer awareness of the clockspeed conflict and potential desire to maintain other relationships with providers such as AOL in the vehicle will challenge that structure.

4.2 Potential open Standards Telematics Supply Chain

Again, with this collision of contrasting value chains moving at different clockspeeds, the traditional automotive supply chain is not going to enable success with telematics. However, as argued in the previous chapter, if the OEMs allow their standards along the clockspeed boundaries to be too open, they will also face an undesirable scenario. In contrast to the traditional automotive supply chain, allowing standards to become too open will result in a supply chain in which many entrants gain a direct path to the customer. This scenario most closely represents the current PC industry, where components of the PC are modular along clockspeed boundaries with fully open standards at those boundaries, and can be purchased as part of the initial PC purchase, or individually as new components come on the market, or customers decide to upgrade portions of their PCs. For example, one may only purchase a new computer every 3 years, but may choose to upgrade the operating system, RAM, hard drive, or network card at different intervals. This is made possible because as these different components advance over time, and at different speeds, they still "plug and play" with the PC due to the modular architecture along clockspeed boundaries with open standards at those boundaries. If the OEMs were to apply the modularity rule along clockspeed boundaries with open standards, then a supply chain similar to that depicted in Figure 3 may arise.

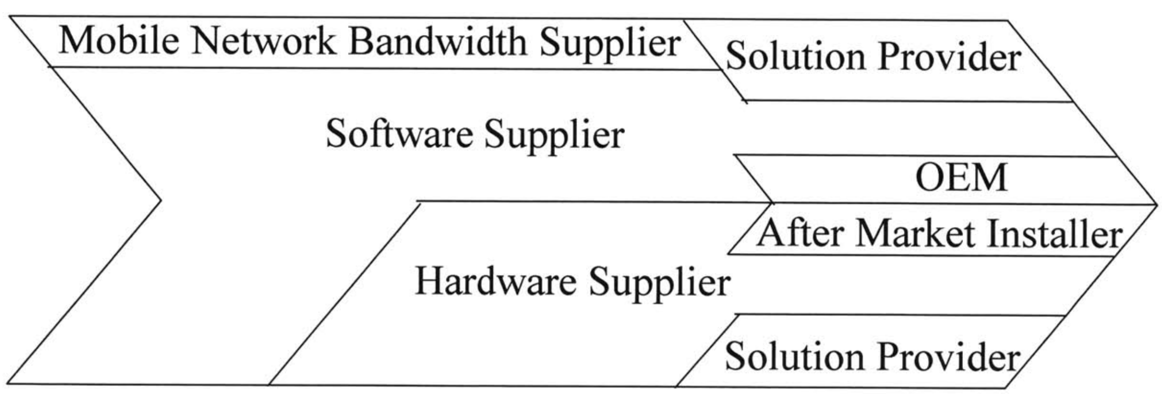


Figure 8: Potential Supply Chain with Open Standards

With open standards at the interfaces, a host of entrants could now gain access directly to the customer, as well as maintain relationships with the OEMs. For example, a customer may purchase a new vehicle with a factory-installed telematics system comprised of pieces from a software supplier, a number of hardware suppliers, and a bandwidth supplier, all integrated into the vehicle by the OEM. As time moves on, if the OEM cannot include technology updates of those subsystems more frequently than the following model year; a software supplier would be able to sell an upgraded guidance program to a customer 6 months after the initial vehicle purchase. This is the structure that non-OEM entrants would prefer, because it not only lets them get the latest technology that the customers demand into their hands on time, it also provides additional avenues for revenue and customer relationships that didn't exist in the previous structure. Conversely, the OEM does not want to lose the profit leverage or control over the customer relationship, and should push for a more restricted structure.

Many entrants at play in the telematics value chain have valued relationships in place with customers (i.e., AOL), or established brand names that customers may demand. While the OEM will strive to establish a supply chain in which they maintain the utmost control (a completely closed standard at the clockspeed collision boundaries), customers and telematics service providers my implement alternative opportunities. For example, many years ago the only way to buy a mobile phone was in an automobile, the car phone. Over time, customers became frustrated with the slow pace at which car phones developed, and adopted mobile phones as other producers brought this alternative technology to market. The same can be said about telematics; OEMs must be careful as to how much control they attempt to hold over telematics products and services, as wireless or yet unannounced technologies may give the customer another alternative. As a result of these forces, and the customers' desire to have flexibility, the final supply chain will probably represent a hybrid of the two extremes.

4.3 Potential Managed Standards Hybrid Telematics Supply Chain

It should be apparent that the most balanced supply chain scenario will result from a combination of the first two situations; one in which the OEMs still maintain control of their proprietary standards at the modular clockspeed boundaries, but exercise due diligence to establish sufficient partnership agreements to provide sufficient flexibility for customer choice to generate a viable market size to support profitability. As stated before, a fully open standard would generate a much larger market than would multiple closed standards, but in returning to the example of the video game console makers, we see that it is possible to thrive in the latter scenario. In the case of telematics, certain relationships with large volume telematics and services providers (such as AOL, OnStar, or MSN) will be necessary to generate enough consumer interest to support the business case, but the OEMs can still determine who gets access to the customer through their systems. Just as the video game console makers have to ensure enough game manufacturers have access to their systems, the automakers will need to provide enough content and services with sufficient flexibility to maintain the market with controlled, proprietary standards.

Controlling the level of standards openness and establishing sufficient partner relationships is one way in which to shape the chain, but in the case of telematics, there is another leverage point. The next chapter explores regulation facing the telematics industry and discusses how the influence of regulation can actually be used in a proactive manner to help shape the supply chain.

Chapter 5: Regulation Environment

Automakers traditionally dislike regulation; they view it as a restriction to their business, and as a driver of increased cost and complexity. Typically, the lobbying efforts spearheaded by OEMs focus on limiting the amount of regulation that is passed, limiting the scope of regulation when it is passed, and minimizing the tightening of regulation over time. Regulation is viewed as a negative, resulting in a strategy that unilaterally fights it as opposed to a strategy that tries to shape regulation strategically in the interests of a business strategy.

Regulation can affect the business in two respects. First, regulation can serve as a restrictive barrier, preventing the automaker from including services or features. Secondly, and sometimes less obviously, regulation may require that certain features or services be provided. Both of these possibilities impact the product architecture decisions.

Traditionally, the automotive industry has been most affected by regulation from the National Highway Traffic Safety Administration, or NHTSA. As an agency within the US Department of Transportation, NHTSA is responsible for regulating and enforcing motor vehicle safety, the national driver register, highway safety, and information, standards, and requirements (i.e., vehicle labeling, bumper standards). With telematics, NHTSA is again involved from a safety standpoint, but due to the use of consumer data with telematics electronic products and services, congress is also involved.

5.1 Congress and Privacy Protection

For customers who use the Internet and wireless services, privacy protection has become a key concern over the past few years. With improved technology that allows easier access to, and flow of information, consumer information is being collected and stored at an ever-increasing rate. What used to be limited to information collected during credit checks, or applications for loans and credit cards has expanded to include information culled from cookies on individual computers viewed during Internet browsing. Legitimate businesses use these databases to target their marketing efforts, resulting in annoying pop-up ads, telemarketing calls, and mass mailings. Far more troubling is the illegal use of this information for criminal activities, such as credit card fraud and identity theft. Over the past two years, congress has acted to put in place several protections for consumer information, and these efforts could have a significant impact on telematics.

On January 20, 2001, congress passed H.R.237, commonly known as the Consumer Internet Privacy Enhancement Act, intended "to protect the privacy of consumers who use the Internet." Ten days later, on January 30, 2001, congress passed H.R.260, commonly known as the Wireless Privacy Protection Act of 2001, with the aim "to require customer consent to the provision of wireless call location information." That summer, on July 11, 2001, congress passed S.1164, commonly known as the Location Privacy Protection Act of 2001, which provided for "the enhanced protection of the privacy of location information of users of location-based services and applications, and for other purposes." Finally, on May 8, 2002, congress enacted H.R.4678, the Consumer Privacy Protection Act of 2002.

These various regulations, as well as others passed in the interest of protecting the privacy rights of consumers, will affect the nature of telematics products and services that the automakers can offer. In some cases, privacy restrictions may prevent automakers from using data in a desired fashion, or may prevent them from selling data to interested parties. In other instances, automakers may be restricted in how they use location data, or may have issues in getting permission to use position data. On the other hand, having the ability to collect that type of data may put an automaker in a position where it is required for some unintended use. With the expansion of wiretapping rights for tracking criminal activities, federal agencies such as the FBI may ask automakers to provide data for such cases. Given the public's fear of such activities, an automaker may want to balance the amount of information that is collected by the telematics package to avoid problems. As an example, Intel had issues when it assigned serial numbers to its PC chips that would make a computer individually identifiable. While the automakers may be within their rights and the law to collect certain data, consumer pressure may prompt them to limit that activity in their systems.

5.2 NHTSA and Driver Distraction

In addition to the privacy concerns being addressed by congress, NHTSA is responding to growing public concern about the safety of increased distractions in the automobile. Numerous news sources have reported on the number of accidents due to driver distraction, particularly from the use of cell phones while driving. In its recently published rulemaking priorities for the 2002 - 2005 time period, NHTSA details plans to directly address driver distraction. Under a heading titled "Prevent Crashes by Reducing Driver Distractions," NHTSA states the following:

> *"The number of in-vehicle technologies and their potential for distractions is expected to increase as more electronic devices appear in cars. NHTSA estimates that driver distraction and inattention contribute to 20 to 30 percent of police reported crashes – about 1.5 million crashes a year. Cell phones have become ubiquitous, and newer advanced technologies, such as heads-up and navigational displays have begun to appear in some vehicles. Rulemaking may be necessary to limit the functions of these technologies that distract drivers while the car is in motion. Some standardized design parameters may be needed to reduce driver confusion."*
>
> *- NHTSA Vehicle Safety Rulemaking Priorities: 2002 – 2005, Section I, Part B*

Two milestones have been established towards this effort. The first is to "conduct research on driver distraction," which began in 2002 and is scheduled to run until 2005. More importantly, NHTSA has set a rulemaking decision milestone for 2004.

5.3 Strategic Leverage through Regulation

So what should entrants in the telematics value chain do in the face of these current and pending legislative efforts? Past behavior would indicate that the automotive industry lobbying groups would work to limit the scope of such regulation to try and prevent these bodies from restricting the kinds of products and services they can offer to the customer. This strategy does not reflect an attitude that driver distraction and other concerns do not need to be addressed, rather that the industry feels that it can study and respond to the issues in a responsible manner that both places the highest regard for safety and establishes a healthy business position.

As a matter of fact, several efforts are already underway on the part of the industry to address the driver distraction concerns. In April of 2002, an article in USA Today profiled the recent release of Human Machine Interface guidelines to try and limit how much high tech gadgets in cars interfere with driving. These 23 principles were developed by the Alliance of Automobile Manufacturers for the design and installation of telematics, defined by that group as electronics and communications that provide guidance and information to drivers. The principles are high level, and seemingly straightforward in nature. Several examples include: "new technologies should not block the driver's view or get in the way of other vehicle controls [,] the driver should be able to complete tasks with brief glances [, and] sounds should not be so loud they mask warnings inside or outside the vehicle." At that time, NHTSA had no plans to regulate the gadgets, but was pleased that the industry had developed them, according to agency spokesman Ray Tyson.

In a more comprehensive effort to define and study driver cognitive load, Ford Motor Company has developed an advanced moving-base driving simulator known as VIRTTEX (VIRtual Test Track EXperiment) that is now being used to conduct research on driver distraction with a number of automakers. A full vehicle is bolted into the simulator, which can move 10 feet to any side, and tilt up to 20 degrees. Drivers are then asked to perform tasks such as retrieving voicemail, changing the radio station, changing a CD, putting on makeup, and other common tasks that distract drivers during their commute. Researchers can then scientifically observe reactions to virtual situations that are competing for the driver's attention, such as traffic, children darting into the street, etc. From these observations, the simulator provides data regarding the cognitive load that a driver can handle, and design systems that respond to the driving environment in a way that situationally allow and restrict certain features and peripherals. For example, the vehicle may sense that it is deviating from the lane in a manner consistent with distracted driving. Knowing that the eject button was just pressed for the CD player, and sensing that the driver is talking through the hands-free car phone, it could deduct that the driver is changing the disc while on the phone. At that point, the vehicle could sound a warning tone accompanied by a tactile vibration in the seat to warn the driver, or interrupt the phone call and lock out the CD player until the vehicle returns to course. The cognitive load data gathered from the simulator provides the limits that can be set on the system, the logic that is used to define how the vehicle responds to distracted driving behavior.

It is important to note that this is not being done in a vacuum. The data gathering that NHTSA refers to in its rulemaking priorities document includes data from VIRTTEX and other sources. So to some extent, by spearheading the study of driver distraction, the industry is helping to shape future driver distraction legislation, but the focus is again to limit the restriction that legislation places on the industry. While in one sense being free to determine what products and services are offered to the customer supports the business goals of the industry, this work suggests that the players in the industry are missing an important leverage point, the ability to not only limit restrictions on products and services, but to also shape the supply chain.

In the case of telematics, an entrant can strategically use lobbying efforts to drive one of the two supply chain scenarios presented in chapter 4. An OEM could argue to NHTSA that they provide the required expertise in system integration and alone have the system design control to meet emergent property requirements such as vehicle safety. Each vehicle is different, and each implementation of telematics would bring a dizzying combination of products and services from any number of suppliers that any one supplier could not have the capability to ensure that a change in their piece would not adversely affect the system function. As a result of that complexity, someone such as a software provider should not be permitted to sell an upgrade to something like a telematics operating system directly to customers since the OEM cannot certify the overall vehicle performance with that change. The legislation should thus require that suppliers who provide such upgrades along the way do so to the OEM, not directly to the customer.

An argument can also be made from the supplier point of view. Since the supplier is the one who provides updates at a faster clockspeed than the OEM, and given the modularity of the telematics system designed along clockspeed boundaries, the supplier could argue that they can provide safety upgrades directly to customers much more quickly than the OEMs, thus saving more lives.

The bottom line is that lobbying efforts and pre-emptive actions such as VIRTTEX and human machine interface design guidelines will help deflect some of the legislative pressure, but the real untapped potential and leverage with regulation of telematics is the ability to ultimately shape the supply chain. Whether an OEM or a supplier, each entrant in the chain has a staked interest in determining the shape of the chain, as the ability to gain direct access to the final customer represents profit leverage. Rather than spending every effort strictly to minimize the limitations that regulation places on the ability to offer certain products and services, entrants in the chain should also be exploiting the ability to use regulation to shape the chain in their favor.

Chapter 6: Product Architecture Strategy

This chapter serves to present a series of architecture design guidelines through the integration of ideas presented in the previous chapters. This does not imply that these guidelines are easy things to do, or that they are even technically feasible, but the company that can most completely implement these guidelines will have the strongest strategy for telematics success. It is also important to note that these guidelines apply beyond just telematics; they can be used to strategize for sustainable competitive advantage anywhere that clockspeed collision boundaries present an issue.

6.1 Design Product Architecture Modularity Along the Clockspeed Boundaries

As presented in Chapter 2, the key issue studied in this thesis revolves around the difficulty with managing an area where two distinctly different value chains for technologies that evolve at different rates intersect. The solution is to design product modularity along the clockspeed boundaries with appropriate standards. If one can decouple the functions of the differing clockspeed subsystems, then those two systems can be independently designed and upgraded according to their respective clockspeeds. As for the standards at the clockspeed boundaries, they should be designed and specified in such a way that if the faster clockspeed subsystem or system meets the requirements of the standard, then it by definition meets the verification and validation requirements of the slower clockspeed system.

6.2 Minimize Fast Clockspeed Architectural Elements

Once the modularity has been structured along the clockspeed collision boundaries, this work suggests that an organization must strive to achieve as much system functionality as possible with the slower clockspeed technology. As people begin to adopt new technologies, they are held back by a fear of obsolescence costs. If the implementation involves a high degree of functionality delivered by the faster clockspeed systems, then the obsolescence costs are higher. This is for two reasons. First, since the subsystems move at a faster clockspeed than the slower subsystems, they need to be replaced and upgraded on a more frequent basis. Second, new technologies tend to cost more as manufacturers move to recover the high research and development costs required to bring new technologies to market. So the customer not only has to replace or upgrade more often, the pieces required to do so are themselves more expensive. The company achieves the most functionality with slower clockspeed technologies while implementing modularity along the clockspeed collision boundary ultimately provides the best value for the customer.

6.3 Architect for Ultra-Compatibility

In the same vain as maximizing the achievement of requirements with slow clockspeed subsystems, another way to help manage the obsolescence fears of customers is to make the solution ultra-compatible. The Hewlett-Packard photo printers demonstrate a fantastic example of this strategy, as shown in Figure 9: Ultra-Compatibility – The HP 7550 Series Photo Printer.

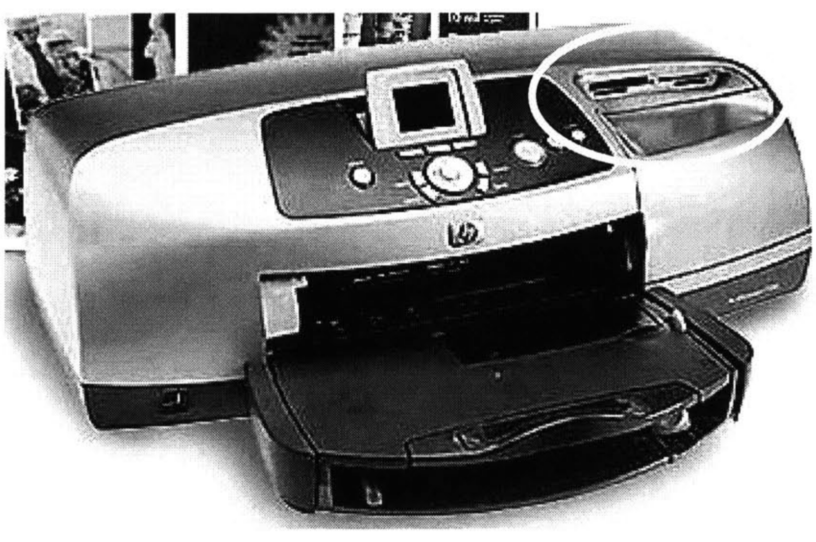


Figure 9: Ultra-Compatibility – The HP 7550 Series Photo Printer[23]

[23] From http://www.hp.com

Highlighted in the oval is a series of slots in which the most common forms of digital media can be inserted. During the development of digital cameras and other devices that use removable, transportable storage medium, the companies employed strategies that resulted in a number of proprietary implementations. With its 7550 series photo printers, Hewlett-Packard has chosen to make itself compatible with a number of these different media. This his led to success with customers because they can be assured that if they buy another complementary product with a different media format, they will still be able to use the printer. This ultra-compatibility also extends to the varying formats in which the digital files themselves are stored. Cameras and digital imaging software packages store the pictures in a wide range of formats, from GIF to JPEG to TIFF and so on. Again, this printer series prints any one of those formats, mitigating additional obsolescence or non-compatibility fears for the customer. If a telematics subsystem provider can implement a solution that works across a range of OEM in-vehicle formats, this ultra-compatibility will drive success. Redundant

6.4 Apply Clockspeed Boundary Modularity at the Platform Level

Clockspeed boundary modularity should be applied at the platform level that best makes sense for the type of product. Why does this matter, why even bring it up? For the case of automotive telematics, it seems pretty obvious; apply clockspeed boundary modularity at the vehicle level. While each OEM should have its proprietary standards at the clockspeed boundary, those standards and modular architecture structure should be common for all vehicles the company makes. This allows for economies of scales within an enterprise.

Where it is necessary to make this distinction is in the case of enterprises that manufacture a wide variety of products or services. Automakers tend to be homogenous product organizations; they generally do not produce non-automotive products. In the case of a conglomerate such as General Electric, which owns businesses that produce everything from light bulbs to dishwashers to jet engines to television programs, the clockspeed boundary modularity must be applied at the business level where homogeneity exists.

6.5 Design Complementary Products, Processes, and Supply Chains

As presented in Chapter 2, one of the challenges facing the implementation of clockspeed collision boundary modularity in telematics is that the generic process used to design and develop automobiles is highly integral in nature. In order to implement the strategies presented in this work, the products, processes, and value chains must complement each other. What that means is that the degree to which the product architecture is modular or integral should align with the degree to which the design and development process is modular or integral, which should in turn align with the degree to which the value chain is modular or integral.

Professor Fine presents this concept of 3-D Concurrent Engineering in Chapter 8 of Clockspeed: Winning Industry Control in the Age of Temporary Advantage. As shown in Figure 10: Overlapping Responsibilities Across Product, Process, and Supply Chain Development Activities, these three interact in key ways, and must be concurrently designed in the common areas. If the three do not complement each other with respect to degree of modularity or integrality, managing this concurrent design is exceedingly difficult.

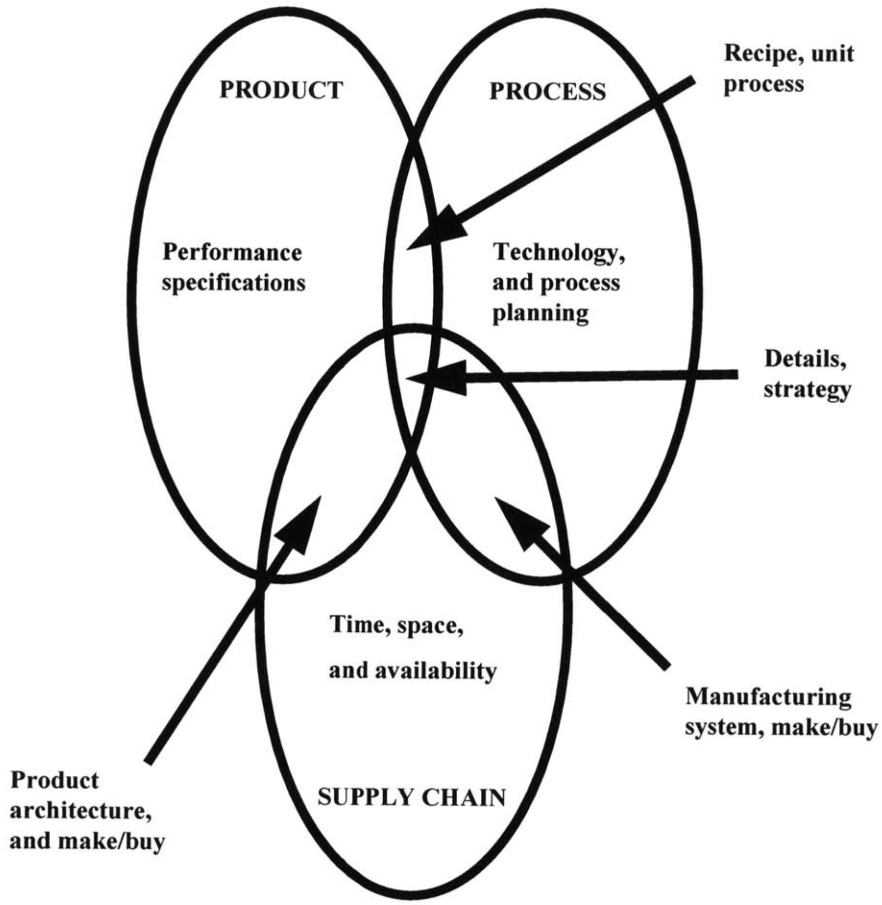


Figure 10: Overlapping Responsibilities Across Product, Process, and Supply Chain Development Activities[24]

It is also important to discuss the dynamic nature of this complementary relationship regarding the level of modularity or integrality. In what is termed as a Double Helix by Professor Fine, firms are always under pressure to move towards the other reality. What that means is that firms that are integral face pressures to moves towards integrality, just as firms that are integral face pressure to move towards modularity. These pressures are depicted in Figure 11: The Double Helix. The automotive industry in general is an integral industry at this point in time, although the last half of the 1990s saw the industry begin to shift back towards modularity. As this swing between modularity and integrality progresses over time, those implementing

[24] Fine, Charles, "Clockspeed: Winning Industry Control in the Age of Temporary Advantage," p. 146.

telematics products and services need to stay ahead of the curve to ensure that their products, processes, and value chains remain complementary and in line with the industry state of modularity versus integrality.

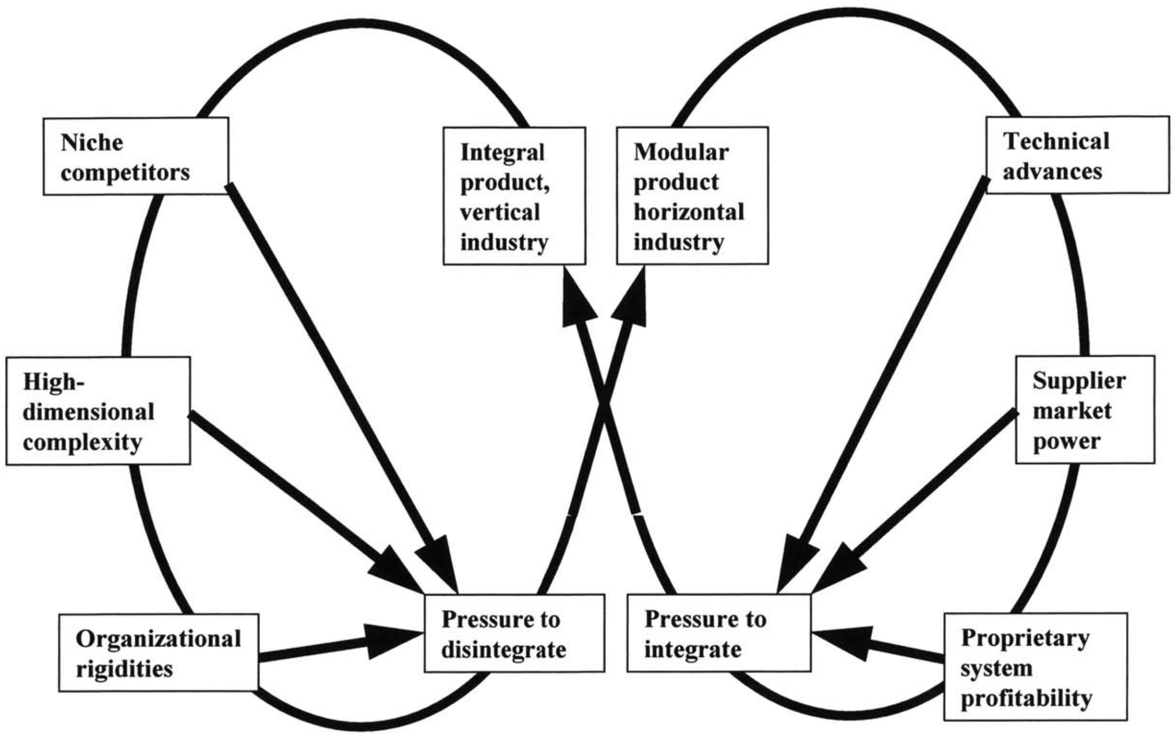


Figure 11: The Double Helix[25]

6.6 Begin With Controlled Standards

This work has conceded that the market uncertainty for telematics is still a short-term hurdle, and it must concede that when the market understanding occurs, the market size may not support a series of OEM controlled standards. But this work emphatically implores OEMs to first strive towards a situation that maintains controlled standards, much in the model of the

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[25] Fine, Charles, "Clockspeed: Winning Industry Control in the Age of Temporary Advantage," p. 146.

video game console, because once a standard becomes open, there is no turning back. Imagine the regret automakers would face if they started with open standards, and then found that the market would indeed support a number of controlled standards that still provided for sufficient content and customer choice.

6.7 Maintain Expertise as the System Architect

One of the key differentiations between an automotive design and development company and an automobile assembly company is the expertise to deliver the complex system emergent properties that customers demand from their vehicles. As the automakers implement clockspeed boundary modularity with telematics, they must ensure that the choices they make as far as standards setting (back to the issue of open vs. closed) do not unintentionally erode their skills as system integrators. Even if a supplier is designing a subsystem, the automaker must ensure that it does not become dependent upon that supplier for the knowledge of the subsystem, because it would fall into the upper right quadrant of Figure 12: The Matrix of Organizational Dependency and Product Decomposability. When one implements a modular architecture, retention of the system integration expertise is paramount.

	DEPENDENT FOR KNOWLEDGE AND CAPACITY	DEPENDENT FOR CAPACITY ONLY
ITEM IS MODULAR (DECOMPOSABLE)	A POTENTIAL OUTSOURCING TRAP Your partners could supplant you. They have as much or more knowledge and can obtain the same elements you can.	BEST OUTSOURCING OPPORTUNITY You understand it, you can plug it into your process or product, and it probably can be obtained from several sources. It probably does not represent competetive advantage in and of itself. Buying it means you save attention to put into areas where you have competetive advantage, such as integrating other things.
ITEM IS INTEGRAL (NOT DECOMPOSABLE)	WORSE OUTSOURCING SITUATION You don't understand what you are buying or how to integrate it. The result can be failure since you will spend so much time on rework and rethinking.	CAN LIVE WITH OUTSOURCING You know how to integrate the item so you may retain competetive advantage even if others have access to the same item.

Figure 12: The Matrix of Organizational Dependency and Product Decomposability[26]

6.8 Interaction with Standards, Supply Chain and Regulation

The key message of this chapter, and of this work, is that any company implementing telematics must understand the dynamic interactions of the issues presented here. They must design their products, processes, and value chains with an implicit understanding of the dynamic nature of these interactions, and re-evaluate their strategy regularly to ensure that it is in step with the market dynamics. By applying the concepts presented in the product architecture strategy guidelines, companies implementing telematics or any product in which colliding clockspeeds present an issue can achieve sustainable competitive advantage.

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[26] Fine, Charles, "Clockspeed: Winning Industry Control in the Age of Temporary Advantage," p. 169.

Chapter 7: Current OEM Offering Strategies

When the research for this thesis began, the author started by sampling the telematics products and services offered by various automakers. The intent was to then use these matrices of product offerings from which to build the rest of the research. As with any research effort that spans an appreciable amount of time, this one too found itself following a different path shortly after these matrices were developed. The author has chosen to include this early work because it provides an interesting summary of the market, and it reveals a few strategic trends of late that don't appear in the rest of this work.

These matrices comprise three regions, the United States, Europe, and Asia. Within each region, several automakers were selected with the intent to map their product offerings and discern what their individual telematics strategies were as best could be told by looking at the product lineup. Another goal was to see if regional differences or patterns in telematics strategy emerged. Shortly after these matrices were populated with the product offerings, this research took a different direction because the common theme of difficulty managing technologies that evolve at different rates had really come to the fore as the key issue.

	North American			
	Ford	Lincoln	GM	Chrysler
Available Products and Services	DVD Entertainment System, HomeLink® , GPS Navigation System	DVD Entertainment System, HomeLink® , GPS Navigation System, Vehicle Communication System	OnStar, DVD Navigation System (Denso)	HomeLink®, UConnect (2003 MY, built on Tele Aid)

Figure 13: North American Telematics Offerings

Of particular interest in the North American segment shown in Figure 13: North American Telematics Offerings is the summertime announcement of Chrysler's UConnect strategy utilizing Bluetooth technology. In brief, the architecture decision amounts to a modular solution in which the Bluetooth wireless standard will be used to allow Bluetooth-enabled devices such as cell phones and PDAs to wirelessly connect with the vehicle's audio system. This appears to be the foundation of a clockspeed boundary modularity strategy. Additionally, Chrysler still maintains control over the way in which these devices interact with the vehicle, assuring the capture of value as a system integrator.

	European					
	Mercedes	Jaguar	BMW	Volvo	Audi	Volkswagen
Available Products and Services	Tele Aid (Motorola Hardware)	HomeLink®, Navigation System (Denso)	On-Board Navigation System, Split Screen software for the BMW Navigation System (available at dealer)	Volvo Navigation System	HomeLink®, OnStar, Audi Navigation System (GPS)	none

Figure 14: European Telematics Offerings

In looking at the summary of European telematics offerings in Figure 14: European Telematics Offerings, BMWs iDrive system stands out. Although a highly integrated system within the 7-Series, BMW does offer a telematics software upgrade at the dealer if the customer desires to have a split-screen option for the display. This is noteworthy because this software upgrade was designed and offered after the initial design of the system, thus demonstrating the scenario where a software provider sells an update to the customer after the initial sale of the vehicle, at the clockspeed of the software evolution. In this case, because BMW has retained control over the architecture, it realizes the revenues for those software upgrade purchases. One additional note for the European list, at the time of compilation during the summer of 2002, Volkswagen did not yet offer telematics products for sale, although its Audi vehicles did.

	Asian			
	Toyota	Acura	Honda	Lexus
Available Products and Services	Toyota DVD Navigation System	OnStar, DVD Navigation System	HomeLink® , Honda Satellite-Linked Navigation System™, Honda DVD Entertainment System	DVD Navigation System (Denso)

Figure 15: Asian Telematics Offerings

The list of telematics offerings on vehicles from Asian automakers, shown in Figure 15: Asian Telematics Offerings did not reveal anything significant, although it was interesting to note that Honda adopted OnStar for its Acura luxury car division. This again demonstrates a modular potential for telematics services packages offered by a third-party company to the automakers. In order to execute that most effectively, it must be designed with modularity at the clockspeed boundaries.

There is an additional significant observation that bears mentioning here. While it doesn't present itself in these particular matrices, several segments of telematics products in the list have emerged with different introduction patterns that one typically sees in the auto industry. Almost universally, new product features and technologies that are introduced in vehicle begin at the high end. They are first introduced in expensive luxury vehicles so that the cost of manufacturing a low-volume new technology is recovered through luxury pricing leverage. Once the new technology gains footing in the market, its application is expanded downward to lower level vehicles, at which point the larger market size allows the automaker to continue to make a profit through volume even though the pricing leverage disappears. The introduction of on-board navigation systems within telematics has followed this strategy, but the entertainment products within telematics have shown a new pattern. The introductions of in-vehicle DVD entertainment systems have occurred first on family use vehicles, such as minivans and sport utility vehicles. Here, the automakers have recognized that profit leverage existed for vehicles in which families make long trips, and that by being able to watch a movie goes a long way to eliminating the ubiquitous question "are we there yet?"

Chapter 8: Conclusion

Automotive telematics technologies are an exciting opportunity for the automotive industry, but they present some significant challenges. First, while this work did not address this issue directly, there is still considerable market uncertainty that is slowing the widespread adoption of telematics. But a larger issue looms once those uncertainties melt away; the differing clockspeeds of the automobile and consumer electronics products and services will make it difficult for automakers to incorporate telematics.

8.1 Conclusion

This research has examined the challenges introduced as a result of integrating fast and slow clockspeed systems and subsystems with automotive telematics. As a result of extensive OEM validation and verification requirements to ensure the vehicle meets performance, cost, reliability, regulatory, safety, etc. requirements, the development time for the automobile runs 3-5 years, while consumer electronics introduce new designs every 6-12 months. In order to introduce telematics products and services in the vehicle at a rate the consumer demands, this work introduced a modularity rule; design modularity along the clockspeed boundary.

Once the modularity is in place along the clockspeed boundary, standards must be established in order to fully allow the fast clockspeed systems and subsystems to be integrated, at the faster clockspeed pace, within the slow clockspeed vehicle platform. In principle, the standards should be designed such that if the faster clockspeed system or subsystem meets the standard, it by definition satisfies the verification and validation requirements of the vehicle itself. With both modularity and standards in place at the clockspeed boundary, telematics products and services can be introduced at a pace appropriate for consumer electronic product demand.

In the case of telematics, the regulatory environment is set to heavily influence the playing field. Concerns over both driver distraction and the protection of privacy rights have led to a number of legislative activities that could restrict telematics capability, or in come cases, require it. Companies that are involved in the telematics arena need to proactively impact the regulatory process in order to shape the value chain in their favor.

Firms must holistically design and manage their product architecture, process, and supply chain and in light of standards and the regulatory environment. Individual strategies require entrants to decide how open or closed to make their architectures and standards, necessitating a fine balance between proprietary profit leverage, commoditization, and customer acceptance. This work asserts that each OEM must, at least initially, implement controlled standards at the clockspeed boundaries. Firms must holistically develop a telematics strategy that considers how decisions regarding open vs. closed architectures and standards impact the supply chain, how regulation and standards will drive product architecture decisions, how firms can influence regulation and standards to their advantage, and they must understand that the dynamic interaction of architecture, supply chain, standards, and regulation together determine who realizes sustainable competitive advantage.

8.2 Areas for Future Research

Two key areas strike the author as interesting directions in which to expand the research on automotive telematics. First, this work accepted the market uncertainty surrounding telematics, but it would be value-added to conduct specific research into the market needs using the framework of this thesis. Would the market wants and needs become more apparent in the context of clockspeed boundary modularity?

The second area of research interest involves expanding this framework to non-physical products and services. For automobiles, airplanes, toys, and appliances, the application of clockspeed boundary modularity is straightforward. But how would one design financial products using the concept of clockspeed boundary modularity? How might a concierge service look in the context of clockspeed boundary modularity? While it may be possible to extend these concepts into these kinds of areas, it is not immediately apparent to this author how that would look.

Finally, this work raises the question of modular vs. integral product design and development processes. An interesting area for future study would be to understand how this process looks in both instances, for most studies of the topic present generic processes that are primarily integral in nature. An interesting point of data would be to cull examples of product design and development processes from industry that represent both ends of the modular vs. integral spectrum, and to evaluate the strengths and challenges inherent to each.