

**WHAT MATTERS MOST: RESEARCHING THE CRITICAL FACTORS FOR  
MAXIMIZING AUTOMOTIVE INNOVATION PROFITABILITY, AND THEIR  
IMPLICATIONS ON SYSTEMS-BASED INNOVATIONS**

by

**Nathan A. Clark**

Submitted to the System Design & Management Program in  
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Nathan A. Clark  
System Design & Management Program  
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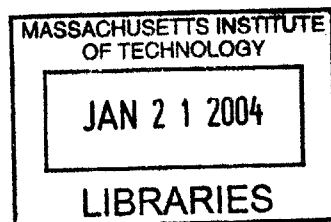
Eric A. von Hippel  
Thesis Supervisor  
Professor, Management of Innovation Behavioral Policy Science (BPS)

Accepted by \_\_\_\_\_

~~Thomas J. Allen~~  
Co-Director, LFM/SDM  
Howard W. Johnson Professor of Management

Accepted by \_\_\_\_\_

David Simchi-Levi  
Co-Director, LFM/SDM  
Professor of Engineering Systems



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**ABSTRACT**

It is predicted by many in the industry that over the next decade automotive OEM's will look more and more like "vehicle-brand owners," focusing efforts on branding, marketing, and building a stronger retail channel. This is especially true of the U.S. automakers, who are today entrenched in a desperate struggle to reclaim their declining market shares from foreign counterparts. As a result, demands placed on tier-one suppliers have increased, competition throughout the supply-chain has intensified, and new strategies for sustainability are needed.

The myriad engineering, development, and validation responsibilities passed down by OEM's have resulted in the formation of a new first-tier supplier – the *systems integrator*. The transition from components to integrated systems and modules has definite implications on the firm's innovation and product development processes. This paper focuses on supplier innovation strategies, and argues that the proper alignment between value creation and value capture aspects of an innovation are required to maximize its profitability potential.

Ten ArvinMeritor (tier-one supplier) innovations are examined in attempt to determine what critical factors had the most impact on profitability (or lack thereof). The results are then placed in a systems context, and a framework is generated to conceptualize the critical inputs to the systems innovation process. The foundation of the framework is depicted as two rotating wheels, the System Architecture (value creation) wheel, and the Revenue Architecture (value capture) wheel. The wheels gain momentum from a number of critical interdependent inputs to the value creation and capture processes, and furthermore, the sustained momentum of each wheel is needed to keep the other in motion. These framework inputs are discussed in detail, and collectively represent a conceptual path forward for ArvinMeritor as it continues its transitional journey to the realm of the systems integrator.

Thesis Advisor: Professor Eric von Hippel

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## 1. Introduction

The premise of many management journal papers regarding sustainability of companies in technology-driven industries contends that *Companies that cease to innovate will cease to exist*. This paper, while in agreement with the above statement, goes a step further by arguing that innovation alone provides no guarantee for sustainability. In other words, the converse of the above premise, *Companies that continue to innovate will continue to exist*, is not necessarily true. This argument implies that innovation in technology-driven industries is a necessary, but not sufficient, means for survival. Taking innovation to the next level, that is, being able to **capture value** from it, is both necessary and sufficient for a firm's survival, and is the main thrust of this thesis. Exploring in depth the value capture aspects of innovation, in terms of profitability, is the paper's primary focus.

The motivation behind this work stems from the impact that U.S. automakers' are having on their global supply chain as they continue to engage in an on-going market share struggle with their foreign counterparts. It is predicted by many in the industry that over the next decade automotive OEM's will look more and more like "vehicle-brand owners," focusing efforts on branding, marketing, and building a stronger retail channel. As this occurs, increasing responsibility for producing, procuring, and assembling vehicle subsystems and components will be assumed by the supply chain, with top-tier suppliers taking the lead. This movement is intensifying competition among suppliers and, when coupled with OEM-mandated year over year cost reductions, is causing all players in a changing supply chain landscape to rethink their strategies for sustainability. Two key ingredients of a sustainable strategy are the firm's ability to create value for its customers by offering innovative new products, processes and services, and its ability to capture value from these innovations. Collectively, these two ingredients can be thought of as a firm's ability to *manage the innovation process*, a defining attribute of survival in an increasingly volatile global automotive supplier sector.

As tier-one suppliers re-define their roles and competencies in the automotive industry, many have begun making the strategic transition from component suppliers to providers of integrated systems and modules. Such a transition has definite implications on the firm's innovation and product development processes. This research will study aspects of the innovation process at ArvinMeritor, a tier-one global automotive supplier. Through the use of ArvinMeritor product development and innovation case studies, focus will be placed on identifying and understanding the factors contributing to innovation value capture (i.e. profitability). The implications that these factors have on the firm's transition to systems-based products will be discussed through the use of an integrated systems innovation framework. By enhancing its understanding of the factors critical to innovation success and the competencies needed to excel in the realm of systems integration, ArvinMeritor can better align its product development and resource allocation efforts with *what matters most*, thereby helping the firm to maximize profitability potential and solidify a sustainable position in a rapidly evolving automotive supplier arena.

## **1.1 Thesis Content**

The thesis begins with a discussion of innovation in section 2, drawing extensively upon knowledge gained from the SDM program and existing literature to introduce innovation and innovation strategies used by firms to sustain and grow their business. Section 3 discusses the current state of the automotive industry, the challenges facing suppliers in a changing supply chain landscape, and the need for suppliers to *innovate* their innovation process to succeed in an emerging systems-based tier-one transformation. Section 4 discusses the research conducted to identify the critical factors necessary for innovation profitability at ArvinMeritor, based on a series of innovation case studies at the tier-one automotive supplier. Section 5 extracts the critical success factors from the research results, discusses their implications specifically on systems-based innovations, and draws conclusions from the work. A framework is presented to illustrate the interdependent nature of the inputs into the innovation process of a systems integrator. Finally, opportunities for further research are identified.

## 2. Innovation – *Classifications & Strategies*

Innovation can come in many shapes and sizes, originating from invention or adoption, and ranging from elegantly simple to deeply complex. This section will discuss the fundamental classifications of innovation, and the strategies used by firms to profit from innovation. The methods and strategies used by firms to innovate new products, processes, and services, combine to form the firm's *innovation process*. The innovation process is one component of the company's overall business strategy, which deals with the analysis of a company's strengths and weaknesses and the opportunities and threats presented by its environment. This strategy determines how a company competes in its chosen business, and looks toward consistent execution of broad plans to achieve certain levels of performance.<sup>1</sup> The innovation process determines to what extent and in what way a firm attempts to use innovation to execute its business strategy. The discussion of the innovation process throughout this paper will be framed in the context of two essential ingredients associated with *value*; the innovation methods and techniques make up the **value-creation** portion, and the strategies employed to profit from the innovation constitute the **value-capture** portion. It is argued that in order for an innovation to succeed, there must be proper alignment between value-creation and value-capture. An innovation, alone, seldom makes money; but an innovation brought to the right market with the right business strategy can change an industry. This discussion of capturing value from innovation will also serve as a preface to the later discussions of the critical factors necessary for maximizing innovation profitability at a tier-one automotive supplier, ArvinMeritor.

### 2.1 Classifications of Innovation

Innovation in the context of this paper is not limited to the introduction of new products, processes, or services, but rather adopts a broader approach (Janszen, 2000) of

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<sup>1</sup> Gilbert, Joseph T., "Choosing an Innovation Strategy: Theory and Practice", Business Horizons, November/December 1994: p. 16-22

innovation as the introduction or implementation of something new, including one or more of the following:

- ✦ a new technology;
- ✦ a new application in the form of a new product, service, or process;
- ✦ a new market or market segment;
- ✦ a new organizational form or a new management approach;

The innovations that come from these categories can be classified in a number of ways. First, they can be classified by their degree of innovation impact, from *incremental* to *radical*. **Incremental innovations** are generally referred to as the refinement and enhancement of existing products, processes, or services, with only minor changes made to their existing architecture or technology content. **Radical innovations**, which are typically smaller in number, cover those cases where an entirely new set of business, scientific, and/or engineering principles overturn existing technology, revolutionize product architecture, and open whole new applications, markets, and even new industries.<sup>2</sup> Automated teller machines (ATM), microwave ovens, and electronic sewing machines are a few examples of radical innovations.

Incremental innovation reinforces the capabilities of established organizations, while radical innovation forces them to ask a new set of questions, to draw on new technical and commercial skills, and to employ new problem-solving approaches.<sup>3</sup> The 35mm camera illustrates this point well, in that since its advent nearly a century ago, for the most part only incremental improvements have been made, such as higher lens quality, better

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<sup>2</sup> Bozdogan, Deyst, Hult, Lucas, "Architectural innovation in product development through early supplier integration", *R&D Management* 28, 3, 1998: p. 163-173

<sup>3</sup> Henderson, Rebecca & Clark, Kim, "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms", *Administrative Science Quarterly*, 35, 1990: p. 9-30



flash synchronization, self-timers, automatic film rewind, etc. This is not to say that incremental innovations are insignificant, since today's single lens reflex (SLR) 35mm camera architecture is quite superior to the first 35mm camera introduced in the early 1900's. Then, in 1995, the industry changed forever with the introduction of the first digital camera, a true radical innovation that has revolutionized the way millions of consumers capture, view, and share images.

Imitations often emerge soon after an invention establishes a product's *dominant design*. The concept of the dominant design is an involved topic worthy of an entire thesis, however the purpose here is to provide only a brief overview of its affect on the innovation dynamics of an industry, and to illustrate the concept with one example: the automobile. A **dominant design** in a product class is, by definition, the one that wins the allegiance of the marketplace, the one that competitors and innovators must adhere to if they hope to command significant market following.<sup>4</sup> Not long after a dominant design emerges, the basis of competition within the industry changes dramatically, evolving from competition among many firms with many unique designs to one of few firms with similar product designs. Utterback illustrates this concept by defining three life-cycle phases of an industry that precede and follow the emergence of the dominant design. These phases are shown in Figure 2-1 with respect to the number of competing firms within the industry.

The early stages of an industry are marked by the Fluid Phase, where the number of firms competing for a piece of the market is growing steadily, and the introduction of unique combinations of technology, function, and form, proliferate. The Fluid Phase ends shortly after the dominant design surfaces, at which time the industry's focus on innovation and competition transitions from product design to that of cost and scale, as well as performance. This marks the Transition Phase. A key attribute of the Transition

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<sup>4</sup> Utterback, James M., *Mastering the Dynamics of Innovation* (Harvard Business School Press, 1994) 24.

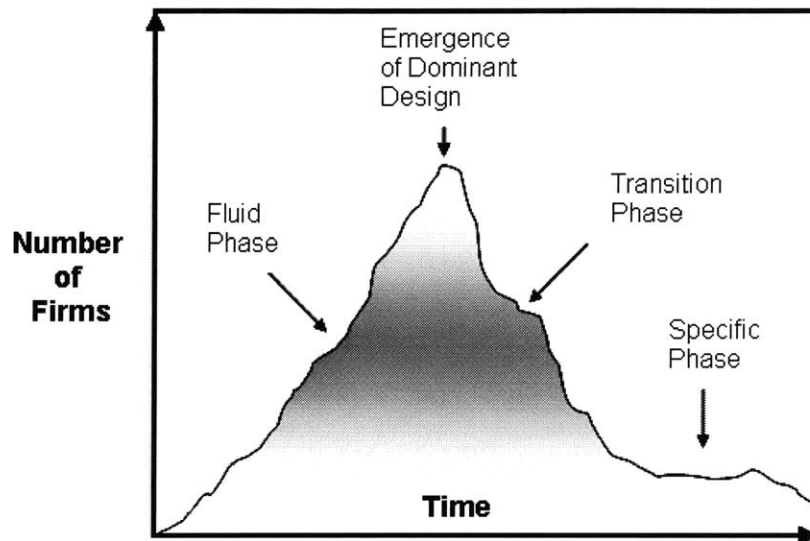


Figure 2-1: Characteristic Phases of Innovation

Phase, as shown in Figure 2-1, is a reduction in the competition base brought on both by firms exiting the industry, and consolidation amongst firms. As this period of competitive volatility subsides, the industry eventually matures and moves into the Specific Phase. The Specific Phase is characterized by relatively stable market share among remaining competitors, developed standards that govern largely undifferentiated products, and an emphasis on process technology and efficiency. Additional attributes of these three industry life-cycle phases are presented in Table 2.1

Barriers to entry are formidable in industries residing in the Specific Phase; however firms are still vulnerable to radical, or breakthrough innovations that can disrupt the industry by establishing a new dominant design that renews the industry's life-cycle. This can be illustrated in the music recording industry, where the dominant design has shifted from records to cassette tapes to compact discs. MP3 digital music technology is the latest disruptive threat to the industry.

	<i>Fluid Phase</i>	<i>Transitional Phase</i>	<i>Specific Phase</i>
<b>Innovation</b>	Frequent major product changes	Major process changes required by rising demand	Incremental for product and with cumulative improvements in productivity and quality
<b>Source of Innovation</b>	Industry pioneers; product users	Manufacturers; users	Often suppliers
<b>Products</b>	Diverse designs, often customized	At least one product design, stable enough to have significant production volume	Mostly undifferentiated, standard products
<b>Production Processes</b>	Flexible and inefficient, major changes easily accommodated	Becoming more rigid, with changes occurring in major steps	Efficient, capital-intensive, and rigid; cost of change high
<b>R&amp;D</b>	Focus unspecified because of high degree of technical uncertainty	Focus on specific product features once dominant design emerges	Focus on incremental product technologies; emphasis on process technology
<b>Equipment</b>	General-purpose, requiring skilled labor	Some subprocesses automated, creating islands of automation	Special-purpose, mostly automatic, with labor focused on tending and monitoring products
<b>Plant</b>	Small-scale; located near user or source of innovation	General-purpose, with specialized sections	Large-scale, highly specific to particular products
<b>Cost of Process Change</b>	Low	Moderate	High
<b>Competitors</b>	Few, but growing in numbers with widely fluctuating market shares	Many, but declining in numbers after emergence of dominant design	Few; classic oligopoly with stable market shares
<b>Basis of Competition</b>	Functional product performance	Product variation; fitness for use	Price
<b>Organizational Control</b>	Informal and entrepreneurial	Through project and task groups	Structure, rules, and goals
<b>Vulnerabilities of Industry Leaders</b>	To imitators, and patent challenges; to successful product breakthroughs	To more efficient and higher-quality producers	To technological innovations that present superior product substitutes

**Table 2.1: Characteristics of Innovation Life Cycle Phases**

This discussion of dominant designs concludes by presenting the industry life-cycle phases in the context of the automotive industry, excerpted from Utterback's "Mastering the Dynamics of Innovation":

More than 100 firms entered and participated in the U.S. auto industry for a period of five years or longer, as presented in [Figure 2-2]. The wave of entry began in 1894 and continued through 1950; the wave of exits began in 1923 and peaked only a few years later, although it has continued until the present day.

Entry of firms into the industry began slowly, but accelerated rapidly after 1900, peaking at 75 firms by 1923. In the next two years, 23 firms, nearly one-third of the industry, left or merged, and by 1930, 35 firms had exited. During the Great Depression, 20 more firms left. The number of U.S. firms in the industry was basically stable between 1940 and 1980, after which a number of foreign producers set up production operations in North America.

A number of major product innovations appear within this pattern of entries and exits. We do not have the data on innovations for the 1894-1918 period, but we assume that during these formative years product innovations were frequent and substantial. The year 1923, when the number of competing firms reached its peak, was the year that Dodge introduced the all-steel, closed body automobile – and important innovation. This new body format dramatically improved the strength and rigidity of the chassis, and at the same time provided an opportunity for manufacturers to move away from hand forming of exterior body panels to the highly capitalized but efficient process of machine stamping.

By 1925, fully half of U.S. auto production was all-steel, closed, body cars; and by 1926, 80 percent of all automobiles were of this type. Exits from the industry began and picked up speed rapidly around this time, and the number and rate of product innovations declined markedly. New concepts that did come along in product accessories and styling were tested in the low-volume, high-profit luxury automobile. Conversely, incremental innovations were more commonly introduced in lower-priced, higher-volume product lines. General Motors appears to have led in both types of innovations, particularly for major product changes. Between 1919 and 1962, the U.S. auto industry witnessed a declining number of major innovations on an annual basis, a decrease in the number of new entrants, and a steady withdrawal of firms from the business [see Table 2.2].

The Dodge all-steel, closed body design was introduced during the period in which fully half the major innovations took place: 1919-1929. While it clearly became the dominant design for the auto body and a major part of the total product package, its

influence on the rate of firm exit and entry cannot be established causally. However, the link between major innovations and the decline of new entrants and increase in exits fortifies our intuition about the linkages here.

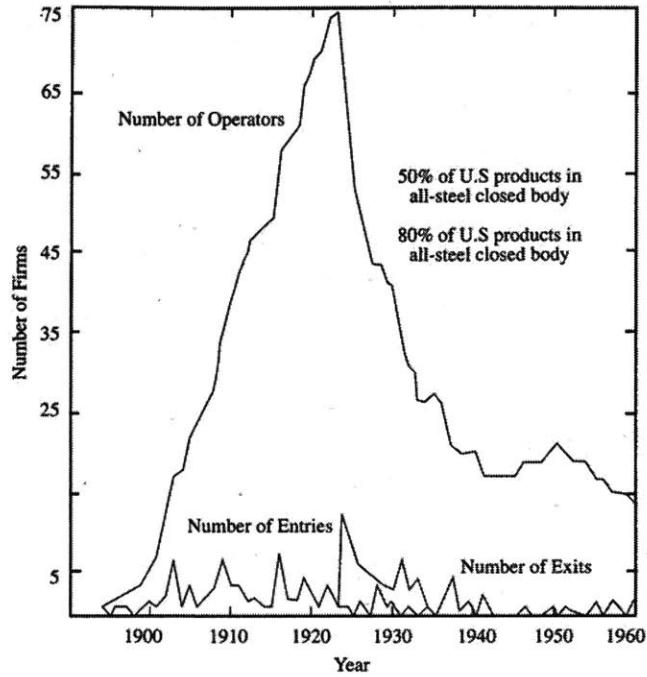


Figure 2-2: Entry & Exit of Firms in U.S. Auto Industry  
1894-1962

<i>Period</i>	<i>Innovations</i>	<i>New Entrants</i>	<i>Firm Exits</i>
1894-1918	NA	60	0
1919-1929	14	22	43
1930-1941	11	6	29
1946-1962	7	4	8

Table 2.2: Automotive Firm Entrants & Exits  
1894-1962

## 2.2 Strategies for Profiting from Innovation

The discussion regarding innovation strategies in this section will focus primarily on entrant strategies employed by firms to profit from their innovation and to optimize its impact on market share. Later sections of the paper will discuss additional value-capture aspects of innovation strategy.

There are essentially two approaches to entering a chosen market with an innovation, either a proactive or reactive strategy. The proactive approach is typically referred to as the *pioneer*, or first-mover, strategy and is generally characterized by a breakthrough, often radical, innovation that is either the first of its kind in its market, or that opens an entirely new market. The reactive approach generally consists of two types of entrants, (1) the fast follower, or *second-mover*, and (2) the *late mover*, and is more likely to be associated with incremental innovations. There are advantages and disadvantages to adopting each of these strategies, as well as a host of differing opinions as to which approach is superior.

The pioneer strategy may be adopted by companies who regard speed-to-market as an essential competitive advantage, or perhaps who wish to portray themselves as leaders in their respective industry. The industry's technology "clockspeed", i.e. the rate of technological change in the industry, also impacts when the firm decides to enter the market. For example, the life cycle of products in the computer industry is measured in terms of months rather than years, and so a company coming to the party 6 months late with their newest computer offering will likely fail. On the other hand, industries such as home appliances or airframe manufacturing have considerably longer product life cycles, and so the dominant players in these industries may not emerge until years after the pioneer entry.<sup>5</sup>

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<sup>5</sup> Gilbert, Joseph T., "Choosing an Innovation Strategy: Theory and Practice", Business Horizons, November/December 1994: p. 16-22

The pioneer strategy carries with it significant risk, in the form of extensive planning and research costs, higher development costs and timing, and uncertainty of market acceptance. However, if done successfully, substantial benefits may be realized. The first-mover advantages include an initial monopoly on the market, and the unique opportunity to set industry standards and shape customer preferences. Schmalensee (1982) has shown that when competition does arrive, even with a physically identical product, the risk of an unfavorable consumption experience motivates rational consumers to continue buying the known pioneering brand. Consumers have tried the pioneering brand and conclude that it works. Therefore, when faced next time with the decision of whether to purchase the pioneering brand or the later entrant's brand, risk-averse consumers prefer the pioneer because of uncertainty associated with the later entrant's product. Thus, simply knowing the pioneering brand works yields a first-mover advantage.<sup>6</sup>

The pioneer strategy can also invoke formidable barriers to entry, especially when the invention offers technological exclusivity through the protection of a patent or copyright. Examples are Eli Lilly's Prozac and Xerox's plain paper copier technology, which allowed both firms to build solid foundations in their respective markets well before the entry of their first competitors. Barriers to entry are also established with the pioneer's ability to create customer switching costs, which are the costs incurred when a customer changes from one supplier or marketplace to another. The higher these costs, the more difficult it is to execute the switch. For example, there is increasing interest in the automotive industry to manufacture exterior body panels out of polymeric material with molded-in color, a technology that would offer substantial weight savings and eliminate the need for paint. However, the high switching costs, which include an enormous OEM investment in the existing sheet steel stamping, processing, and painting equipment infrastructure,

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<sup>6</sup> Huff, Leonard C., and Robinson, William T. "Note: The Impact of Leadtime and Years of Competitive Rivalry on Pioneer Market Share Advantages", *Management Science*. Vol. 40, No. 10, October 1994: p. 1370-1377.

the cost of ancillary polymer molding and forming equipment, and associated product redesign, are maintaining steel's dominance as the OEM body-panel material of choice.

A second strategy for market entry is that of the "fast-follower" or second-mover. While this strategy was placed in the reactive category, it may be more appropriate to refer to second-movers as "opportunists" who attempt to capitalize on the pioneer's invention, its shortcomings, and its resolution of market uncertainty. Even when the pioneer isn't making any obvious mistakes, an attacker can gain by innovating on the pioneer's product or the way it is marketed. Second-movers can benefit by expending only a small fraction of the design and development costs incurred by the pioneer. This frees up time for the second-mover to gage market acceptance of the new product, and to find a way to improve upon it to capture a significant share of the market.

Several empirical studies suggest that the second-mover's ability to gain market share on the pioneer is inversely proportional to the lead-time that the pioneer enjoys, in other words the length of time the first-mover has a temporary monopoly versus a later entrant.<sup>7</sup> As this lead-time increases, the pioneer is given increased opportunity to develop sustainable market share advantages by establishing brand familiarity and reliability, and preempting later entrants with key product line extensions. Therefore, it is in the second-mover's best interests to keep this lead-time to a minimum. This notion of lead-time also represents the basic separation between second-movers and late-movers. Late-movers often introduce an innovation because many competitors have already done so, posing a real threat to their position in that market, or in a complimentary market.

Another measure of the second-mover's ability to gain market share is the length of time the second-mover can sustain competition with the pioneer, referred to as competitive rivalry. Increasing the years of competitive rivalry tends to increase the later entrant's relative market share. This is consistent with Scherer and Ross (1990, ch.10) who

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<sup>7</sup> Huff, Lenard C., and Robinson, William T. "Note: The Impact of Leadtime and Years of Competitive Rivalry on Pioneer Market Share Advantages", *Management Science*. Vol. 40, No. 10, October 1994: p. 1370-1377.



conclude that dominant firm market share levels gradually decline over time because it is usually more profitable to gradually sell off market share than to hold on to each and every customer.<sup>8</sup>

So when does it make sense to be the pioneer, and when should a firm “wait and imitate”? It seems there is no hard-and-fast rule, or single recipe for success that answers this question. Rather, it is hypothesized that implementing a successful strategy that captures value from an innovation involves the proper systematic alignment of a number of factors, both internal and external to the firm, which may even be different for two innovations within the same industry or even the same market segment. Identifying and understanding the critical factors leading to (or detracting from) innovation profitability for select ArvinMeritor products is the main focus of Sections 4 and 5.

The above notion that two different innovations may require the alignment of different critical factors to achieve success suggests that the strategy, or business model, required to maximize profitability for each innovation may need to be established on a case-by-case basis. Large organizations have a difficult time “mixing and matching” innovation strategies, and tend to lean toward one end of the innovation spectrum, and stay there. This practice evolves into a defining characteristic of the firm’s culture, and is described as its *dominant logic*. The dominant logic, put forth by Prahalad and Bettis, is needed to organize and coordinate the actions of the many disparate actors inside the organization. Without it, the company would find itself in constant meetings to coordinate even trivial tasks. A strong internal logic enables individuals and groups to anticipate the appropriate way to consider various actions and to make a choice that will fit with the initiatives of others in the firm.<sup>9</sup> The concept of the dominant logic is a double-edged sword. While it allows the organization to function more efficiently, it runs a great risk of missed

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<sup>8</sup> Scherer, F. M. and David Ross, Industrial Market Structure and Economic Performance, 3<sup>rd</sup>. ed., Houghton Mifflin Co., Boston, MA, 1990.

opportunities, failed initiatives, and vulnerability to disruption. These issues will be addressed in the next section, as the discussion of the changing role of innovation in the automotive industry unfolds.

### **3. The Automotive Industry in the 21<sup>st</sup> Century – *A State of Turbulence***

Figure 2-2 in the previous section portrayed the autobody design as a mature innovation, residing deep within the Specific Phase. In general, a similar curve can be drawn for the automotive industry as a whole in the second half of the 20<sup>th</sup> Century, where predominately only incremental improvements have been made. In-line with the characteristics of the specific phase (Table 2.1), the bulk of innovations have moved to the supply base where competitive advantages are gained through product and process improvements, efficiencies, and economies of scale. However, after gaining momentum in the 1990's, the 21<sup>st</sup> Century Automotive Industry has seen exciting innovations in the areas of advanced lightweight material applications, telematics, sensor technology, safety, and environmental friendliness. These innovations have predominately emerged from the supply chain, which is currently in a state of volatile transformation and by itself resembles an industry in the Fluid Phase. Emerging OEM trends (and constraints) are causing intensified competition among tier-one suppliers, and are dramatically changing supply chain structures and strategies. This section will elaborate on the turbulent state of the automotive supplier sector, describe the specific challenges facing tier-one suppliers going forward, and discuss the re-defining role of innovation as an essential ingredient for sustainability. In order to fully appreciate the changing role of automotive suppliers, it is first necessary to understand the current trends and challenges of the OEM sector, from which supplier trends are driven. While similar trends are occurring in both the light vehicle and commercial vehicle industries, the focus of this discussion will be on the light vehicle market.

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<sup>9</sup> Chesbrough, Henry. *Open Innovation – The New Imperative for Creating and Profiting from Innovation*. Harvard Business School Press, 2003. Chapter 4 Notes.

### 3.1 State of the Automotive Industry – OEM Trends

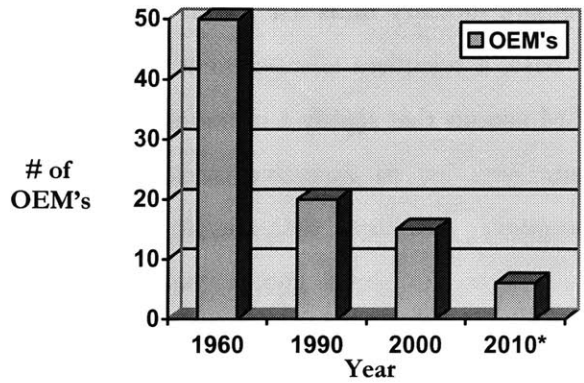
The 21<sup>st</sup> Century automotive industry finds itself in an environment characterized by a shrinking global OEM base, a relentless advancement by foreign OEM's on U.S. and global markets, and OEM actions that signify a changing value proposition. In addition, difficult economic times have led to excessive overcapacity, resulting in prolonged consumer incentive programs that have dramatically eroded domestic OEM profit margins. Figure 3-1 illustrates the global light vehicle OEM consolidation that has occurred in the latter half of the 20<sup>th</sup> Century, with the 6 principal automakers highlighted in red accounting for more than 80% of the total worldwide light vehicle production.

Because the Japanese car market remains depressed, Japanese manufacturers have been forced to seek profitability by moving production overseas and gaining vital market share in the largest markets, namely North America and Europe, with China as a longer term target. Japanese OEM's are increasingly being seen as quasi-US companies (similar to the way Ford is seen as a "European" company when selling its models in Europe), setting up significant vehicle production and parts sourcing within the US. This has allowed Japanese OEM's to make significant inroads into the North American market, forcing the US big three (Ford, GM and DCX) into offering zero % interest incentives in order to compete with the popularity of the Japanese brands.<sup>10</sup> Despite these huge incentives, U.S. automakers have seen their sales drop modestly in recent years. Conversely, Toyota, Honda, and BMW have seen their market share continue to rise on relatively low incentives. In fact, the Big Three market share dropped to 63 percent in 2002 from 73 percent just five years prior, and some estimates have it declining to 50 percent by 2010.<sup>11</sup> US automakers are desperately trying to reverse this trend by slashing their supply base, mandating year-over-year price reductions from those suppliers that remain, and focusing on internal cost and waste reduction. The controversial roughshod approach that the Big

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<sup>10</sup> Wylie, Philip, "Japanese Companies Dominate PricewaterhouseCoopers Global Automotive Shareholder Value Indices", January 17, 2003, [www.pwcglobal.com](http://www.pwcglobal.com).

<sup>11</sup> Yost, Mark. "Tariffs assailed at auto meeting", The Courier – Journal, April 10, 2003.



\* Estimate

### Global OEM Consolidation in the Automotive Industry

#### Europeans

1. VW-Audi-Seat-Skoda-Rolls Royce, Bugatti
2. Fiat-Alfa Romeo-Lancia-Ferrari
3. PSA-Peugeot-Citroen
4. Renault-Nissan
5. BMW Group
6. Porsche

#### Japanese

10. Toyota-Daihatsu
11. Nissan-Renault
12. Honda
13. Mitsubishi
14. Suzuki
15. Subaru

#### Euro-Americans

7. GM-Opel-Vauxhall-Saab-Isuzu-Fiat
8. Ford-Jaguar-Volvo-Lincoln-Mercury-Land Rover-Aston Martin-Mazda
9. Daimler Chrysler

#### Koreans

16. Hyundai-Kia
17. Daewoo-Ssangyong-Samsung

Figure 3-1: Global OEM Consolidation in the Automotive Industry

Three have taken in “trimming their fat” has caused discontent and a collective push-back by tier-ones, with the pressures being felt like a shockwave throughout the entire supply chain.

Other trends and strategic actions occurring across the global automotive industry suggest that OEM’s are shifting toward a new value proposition, moving in the direction of becoming “vehicle brand owners” who focus on vehicle styling, final integrative assembly, marketing & brand management, and building a stronger retail channel (Figure 3-2). As this occurs, increasing responsibility for producing, procuring, and assembling complete vehicle subsystems will be assumed by the supply chain, with top-tier suppliers taking the lead. In addition, as OEM’s continue to expand their current and emerging global markets, they are choosing suppliers with matching global capabilities. These actions are driving radical change throughout the supply chain.

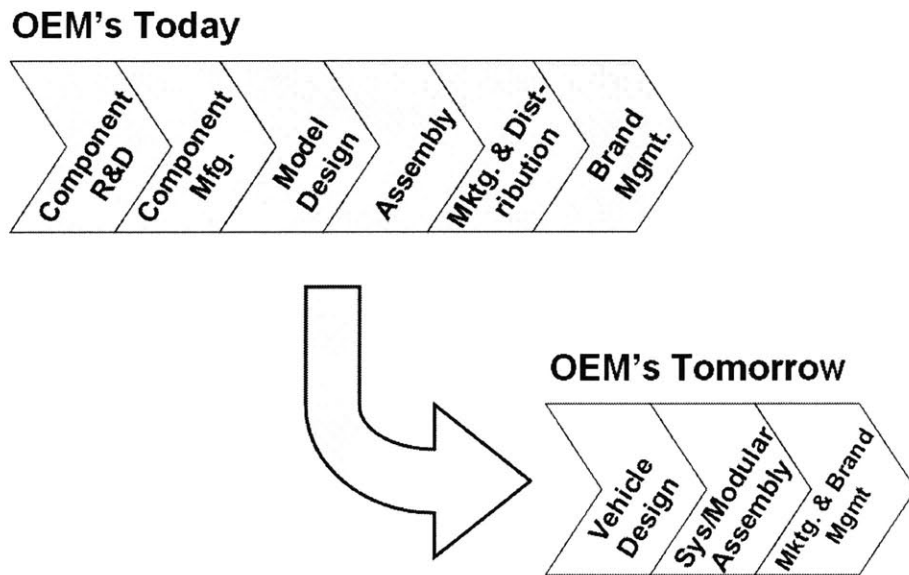


Figure 3-2: Evolution of OEM Competencies<sup>12</sup>

<sup>12</sup> Ernst & Young LLP Report: “Profile of Tomorrow’s Automotive Supplier”, 1998.

Before continuing with discussions regarding *systems*, it is perhaps a good time to define the term in the context of this work, with respect to two related terms, *components* and *modules*.

A **component** is defined in this work as a non-complex part or assemblage of parts that provide an intended function (i.e. a front axle assembly). A **module** may be thought of as the bundling of various components or assemblies into one integrated product offering. One example is an independent suspension corner module, which might combine a shock absorber, a coil spring, and brake components into one product. The complexity of a module is typically greater than that of a component.

A **system**, on the other hand, may be thought of as a collection of inter-related elements (i.e. components, modules, or sub-systems) that produces functionality greater than the sum of its independent elements. A system is considered more complex than a module, and the complexity of the system is typically proportionate to the number of its parts. In general, systems represent groups of elements that are linked by function rather than by location. For example, the different parts of an automobile's safety system or its braking and traction control system are located in separate areas of the vehicle and incorporated into several different modules, but they will have been designed to work together as a complete system.

Increasingly, automotive systems are becoming more complex, driven by the automotive industry's growing environmental, safety, performance, reliability and durability requirements and by the emergence of new technologies, enabling a greater range of functions to be offered to the vehicle owner.

### 3.2 Supply Chain Turbulence – New Challenges Facing Automotive Suppliers

The automotive supplier industry is in the midst of an extraordinary transformation. Mounting OEM cost, quality, globalization, and system integration pressures discussed above have led to a dramatically changing supply chain landscape characterized by mega-mergers and acquisitions that have taken place over the past five years, resulting in a new breed of top-tier full-service integrated systems providers. 1998 and 1999 together saw more than 500 merger and acquisition (M&A) transactions occur in the automotive supplier industry, valued at more than \$65 billion (Figure 3-3). The majority of this M&A activity was done to increase the supplier's global reach and to develop the capabilities to offer integrated system designs. The requirement to deliver systems and modules, along with the ability to supply on a global scale, has created a wave of strategic alliances that have swept across the automotive industry.

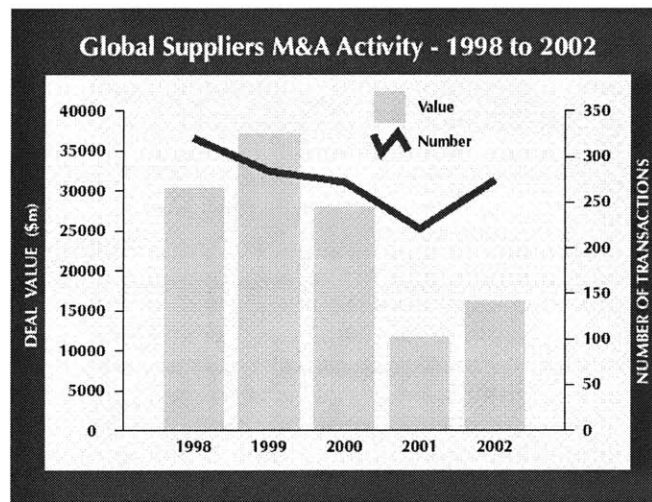


Figure 3-3: Global Automotive Suppliers Merger Activity  
(Source: *Automotive Sector Insights*, PriceWaterhouseCoopers)

The emergence of the integrated systems supplier is redefining the top end of the supply chain, and forcing current tier-one suppliers to rethink their strategy for sustainability. A new first tier is forming, with industry surveys predicting that the roughly 800 tier-one suppliers that existed in 2001 will drop to approximately 30-40 new tier-one system

integrators by 2010.<sup>13</sup> The balance of the old first tier, or direct suppliers, faces a critical strategic decision: whether to pursue a system integrator role, or remain in their current business, which would lower their position in the chain to one of a second- or third-tier role, and increase their risk of being acquired by the consolidation-hungry mega-suppliers.<sup>14</sup> We will see in the next section that ArvinMeritor has chosen to compete in the realm of the systems integrator, which presents its own set of complex challenges.

While OEM's retain their dominance over suppliers, the continuing trend of mega-supplier growth may have significant implications on the automotive food chain. Increasing supplier responsibilities, combined with a decreasing supply base and greater OEM standardization, arms suppliers with new leverage. As the relatively few systems integrators emerge, the number of competitive options available to OEM's will become limited. This poses two risks to automakers, namely the partial concession of its strong-armed pricing and cost-cutting leverage, and the reputation and manufacturing risks associated with the OEM putting all its eggs into one "integrated system" basket. However, as long as the OEM's remain in control of all sales channels to end customers, are substantially larger than their supply base, and continue to lure suppliers with massive global contracts, their supremacy atop the automotive industry is not likely to change.

### **3.3 The Need to *Innovate* Supplier Innovation**

Increasing responsibilities placed on the new breed of tier-one system integrators presents new challenges for sustainability. Traditionally, products and services offered by OEM suppliers were based upon components or assemblies, whose designs were most often controlled by the OEM. Suppliers were responsible for manufacturing these components and verifying that they met all component property and performance specifications, which were also provided by the OEM's. Tier-ones must now develop competencies in the integration of these components and assemblies into complete

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<sup>13</sup> PriceWaterhouseCoopers: "Automotive Industry Survey 2002"

<sup>14</sup> Ernst & Young LLP: "Profile of Tomorrow's Automotive Supplier", 1998.



subsystems. This challenge, taken into consideration with the other OEM cost, quality, and timing pressures, is forcing suppliers to take a hard look at the cost and efficiency of their current component designs as well as the ability of their predominately component-based internal development processes to handle the complex integration and commercialization of complete systems.

Developing these new systems-based competencies is no trivial feat, and requires enterprise-level collaboration, knowledge transfer, and value creation through new methods of innovation. In fact, Chesbrough<sup>15</sup> argues that the innovation game has changed, and that large firms, who have traditionally relied on internal development of internally-generated ideas, can no longer sustain their businesses by continuing this practice. Old habits die hard however, as the following brief digression explains this nearly century-old practice of US firms' vertically-integrated innovation and development processes.

For most of the twentieth century, large corporations produced new products by applying the technologies and innovations developed internally within their own central research laboratories. Chesbrough cites a number of reasons that drove most corporations in the early to mid 1900's to invest heavily in the development of cutting-edge internal research facilities for generating new product technologies. These reasons included the resistance and disinterest of the science community at that time to apply their research to practical problems, the lack of financial resources at universities to fund research projects, and the very limited role of the government in organizing or funding science. However, following a number of government-backed innovation breakthroughs during WWII, the government significantly stepped up its funding efforts to both universities and industry, which added tremendous fuel to the internal corporate research fire. Finally, the internal research impetus continued with the advent of a number of enormous commercial scientific achievements, including superconductivity at the T.J.

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<sup>15</sup> Chesbrough, Henry. Open Innovation. 2003. Introduction.

Watson labs at IBM, a number of innovative new chemical fibers developed at DuPont laboratories, and the use of electrostatic charges to fix toner onto paper, called xerography, introduced by a young company named Xerox.<sup>16</sup> Many other laboratories, including Bell Labs, General Electric, and Sarnoff Labs at RCA followed suit with major expansions of their R&D facilities. ArvinMeritor was no different. With 20<sup>th</sup> Century roots in the then-huge Rockwell International multinational conglomerate, the company invested heavily in Rockwell's central research facility, the Rockwell Science Center, for new product R&D. In short, in-house research had become embedded in U.S. corporate culture.

### *Open Innovation*

Today, with new technologies emerging in all industries in all parts of the world, customers are demanding increasingly complex products. To meet these demands, Chesbrough argues that companies must turn away from their vertically integrated, *closed innovation* focus, and instead practice what he refers to as *open innovation*. Open innovation is defined as:

a paradigm shift where valuable ideas can come from inside or outside the company and can go to market inside or outside the company as well. This approach places external ideas and external paths to market on the same level of importance as that reserved for internal ideas and paths to market during the Closed Innovation era.

The difference between the closed and open innovation paradigms is represented visually in Figures 3-4 and 3-5. Figure 3-4 depicts closed innovation, and is similar to the product development funnel found in most texts on managing R&D. Projects enter the funnel on the left and are subjected to a series of internal filters that weed out *false positives*, which are projects that look initially appealing but turn out to be disappointing.<sup>17</sup> The remaining projects are thought to have the greatest potential for success and are further developed and brought to market on the right. Firms caught in the closed innovation paradigm,

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<sup>16</sup> Chesbrough, Henry. *Open Innovation*. 2003. Chapter 2.

<sup>17</sup> Chesbrough, Henry. *Open Innovation*. 2003. Introduction.

especially those organizations that have established themselves as long-standing market and industry leaders, often tend to focus solely on their core competencies. This causes the internal innovation filtering processes to discard not only the false positives, but also *false negatives*, which are innovative ideas that may have significant merit but are not aligned with the organization's core business strategy. While in some cases the organization may elect to protect some of this non-core intellectual property, it is usually "put on the shelf" and never pursued. The situation becomes somewhat paradoxical in that when organizations *do* attempt to grow their businesses into new markets by pursuing innovative product or technology concepts, there is often overwhelming pressure from the board of directors, shareholders, and Wall Street to instead remain focused on what the company does best, especially if the near-term size of the innovation's potential market is not thought to be significant.

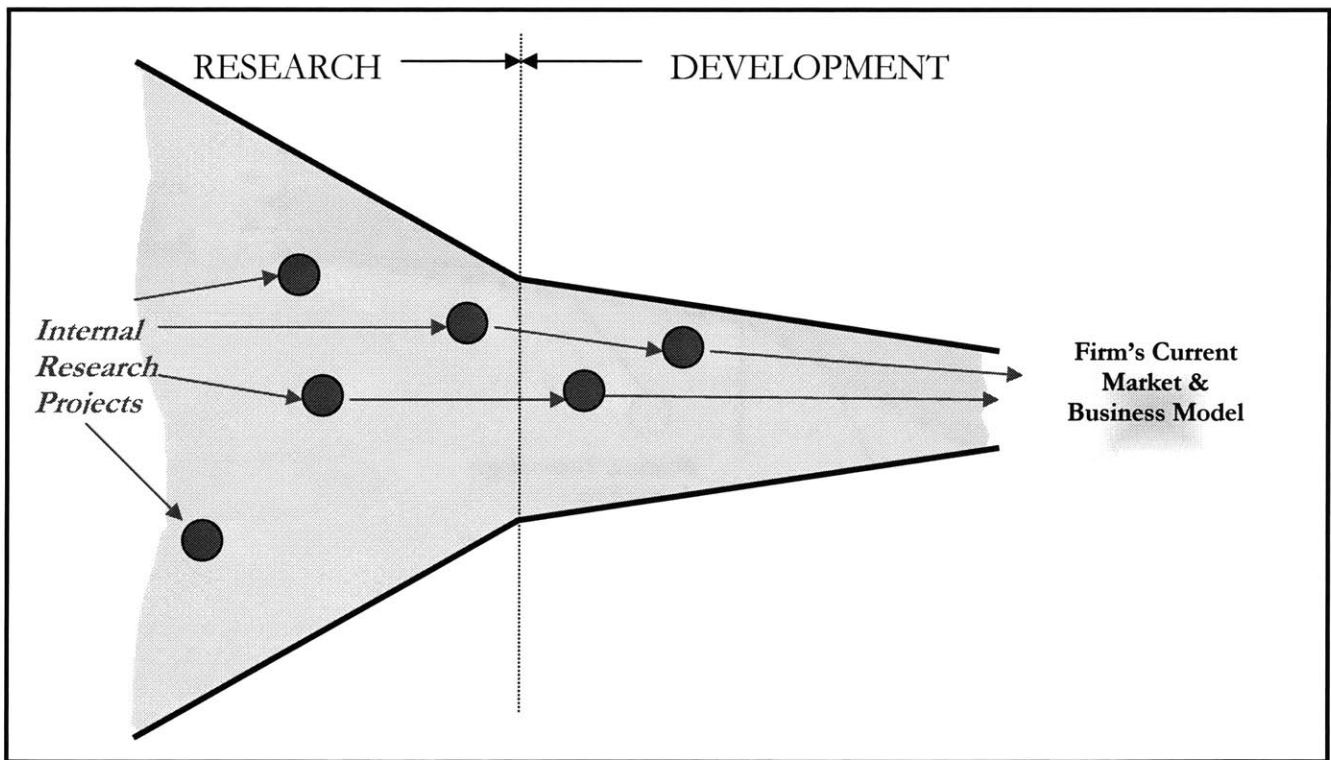
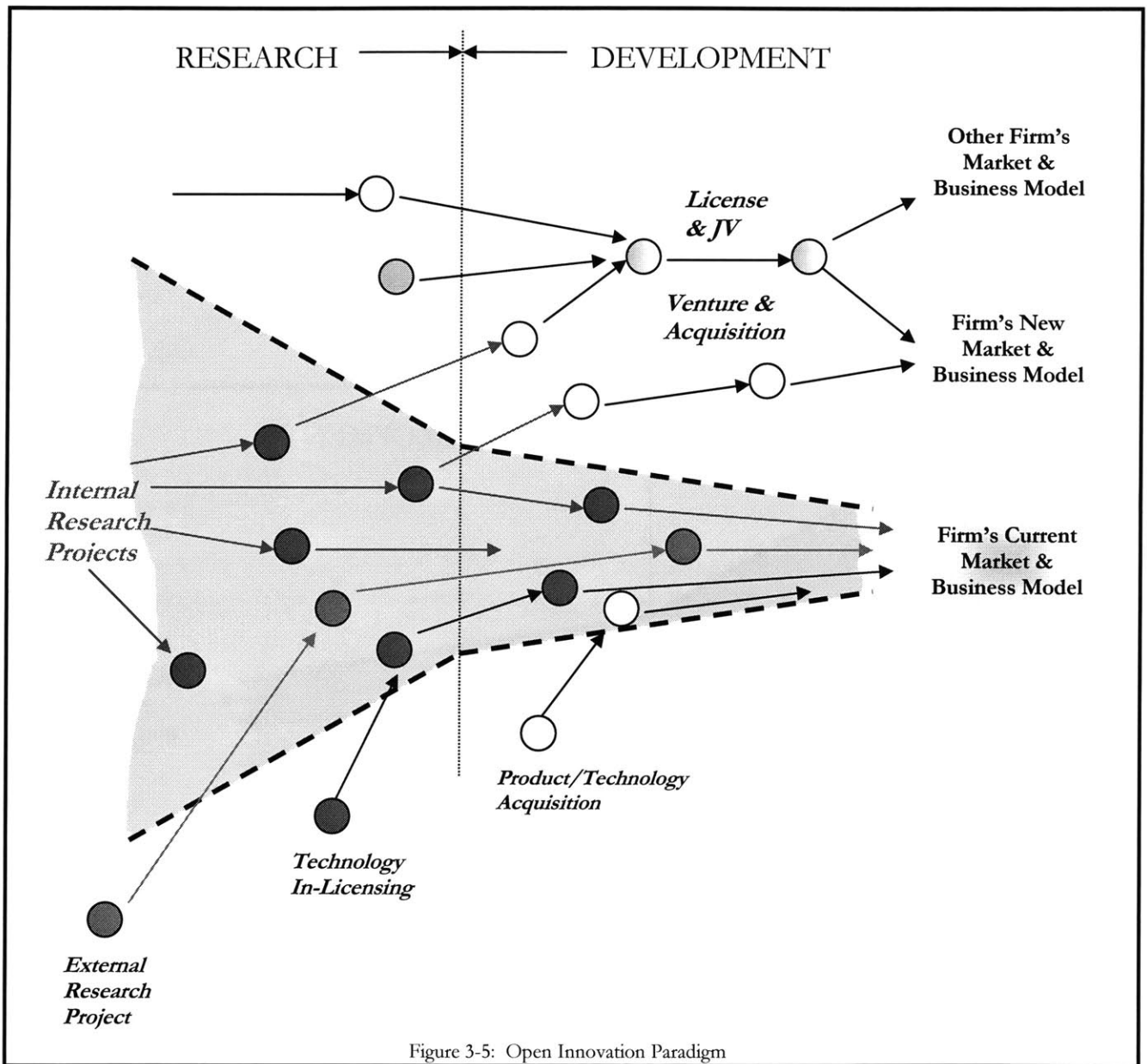


Figure 3-4: Closed Innovation Paradigm

The Open Innovation paradigm offers a very different approach for managing R&D and its false negatives by utilizing alternative paths to market, and alternative markets (Figure 3-5). Numerous potential technologies, innovations, and development projects are now available to the firm as sources of value creation. The dashed lines represent a now pervious R&D funnel, which allows ideas and technologies to flow both into and out of



the firm. The green circles within this funnel constitute the internal research projects shown in the closed paradigm, however the Open Innovation framework warns that by focusing predominantly on these types of projects, firms are potentially missing out on a number of opportunities to grow existing markets by pulling in innovation from outside sources such as external research projects, technology in-licensing, and product/technology acquisition. The order in which these external sources appear in Figure 3-5 (below the funnel) from left to right, is indicative of their relative uncertainty; for example, external research projects may involve a significant development effort before value can be realized, while acquiring an existing product or technology may require much less effort, with the tradeoff of a higher price tag.

In addition to capitalizing on external innovation, potential value creation exists by taking innovation outside the firm to explore new markets using new business models. Opportunities here include spinning-off new technology ventures, forming strategic alliances and partnerships, and licensing out technologies.

This thought model is certainly apropos to the systems transformation taking place among tier-one automotive suppliers. These suppliers must realize that innovative ideas are not scarce, but rather are abundant and widely distributed across many of today's industries. Quite complimentary to the concept of Open Innovation and the need to actively pursue knowledge on a global scale are two additional innovation process concepts: the *Lead User Process* by Eric von Hippel, and the theory of *Metanational Corporations* by José Santos, et al. These will be discussed briefly here.

### ***Lead User Process***

The lead user process offers a systematic and fundamentally different approach for developing breakthrough products. The process is based on the premise that all processes designed to generate ideas for products begin with information collected from users. What separates companies, argues von Hippel, is the kind of information they collect and from whom they collect it. Rather than the typical practice done by most

companies of collecting information from users at the center of their target market, the lead user process is designed to collect information about both needs and solutions from the leading edges of a company's target market and from other markets that face similar problems in a more extreme form.<sup>18</sup> The common approach of conducting focus groups, and analyzing sales data, field reports, customer complaints and requests, etc., assumes that the role of the firm's design and development team is to turn this information into creative new product ideas, relying solely on their internal creative skills to do so. The lead user process makes a different assumption; it says that savvy users outside the company have already generated innovations, and the role of the firm's design and development team is to track down especially promising lead users and adapt their ideas to the firm's needs.

Von Hippel et al<sup>19</sup> state that the lead user process, which makes the generation of breakthrough strategies, products, and services systematic, is based on two major findings by innovation researchers. First, it was discovered that many commercially important products are initially thought of and even prototyped by users rather than manufacturers. Second, they found that such products tend to be developed by companies, organizations, or individuals that are well ahead of market trends and have needs that go far beyond those of the average user. These discoveries, summarized by the Lead User Curve in Figure 3-6, transformed the difficult job of creating breakthroughs from scratch into a systematic task of identifying lead users – companies or people that have already developed elements of commercially attractive breakthroughs – and learning from them.

A step-by-step description of the Lead User Process is given in Appendix C, however an example is presented here to illustrate how the process would be applied in the automotive industry:

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<sup>18</sup> von Hippel, Thomke, Sonnack. *Creating Breakthroughs at 3M*. Harvard Business Review. Sept-Oct 1999. p 49.

<sup>19</sup> von Hippel, Thomke, Sonnack. *Creating Breakthroughs at 3M*. Harvard Business Review. Sept-Oct 1999. p 48.

If an automotive company wanted to design an innovative braking system, it might start by trying to find out if any innovations had been developed by groups with a strong need for better brakes, such as auto racing teams. The company wouldn't stop there, however. Next it would look to a related but technologically advanced field where people had an even greater need to stop quickly, such as aerospace. And, in fact, aerospace is where innovations such as antilock braking systems were first developed: military aircraft commands have a very high incentive to design ways to stop their very expensive vehicles before they run out of runway.

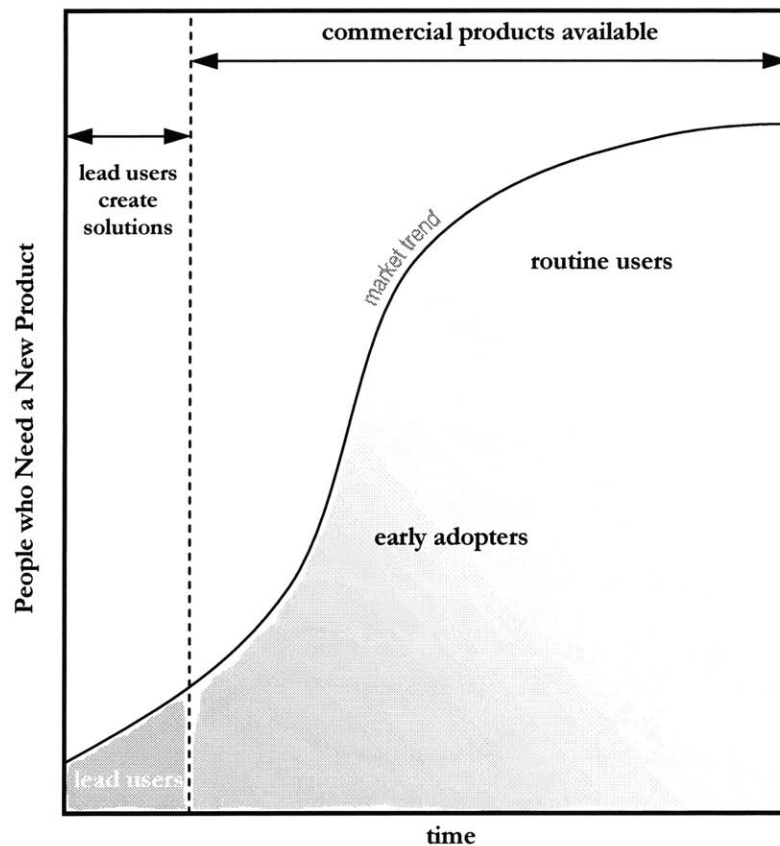


Figure 3-6: Lead User Curve

### *Theory of Metanational Corporations*

Doz, Santos, and Williamson's "metanational" theory is an interesting concept that builds upon the lead user process, emphasizing its importance in a global context. These academic scholars assert that:

"Yesterday, becoming a global company meant building an efficient network of production, sales and service subsidiaries capable of penetrating markets around the world. But the demands of the new knowledge economy are turning this strategy on its head. Today the challenge is to innovate by learning from the world. Tomorrow's winners will be companies that create value by searching out and mobilizing untapped pockets of technology and market intelligence that are scattered across the globe."

The metanational corporation (*meta* – from the Greek term for 'beyond') is one that does not draw its competitive advantage from its home country, not even from a set of national subsidiaries. Rather, metanationals view the world as a global canvas dotted with pockets of technology, market intelligence, and capabilities. They see untapped potential in these pockets of specialist knowledge scattered around the world. By sensing and mobilizing this scattered knowledge, they are able to innovate more effectively than their rivals.<sup>20</sup>

The theory contends that in order to build a metanational advantage, a company needs to extend its capabilities to compete at three distinct levels: *sensing*, *mobilizing*, and *operationalizing*. The first level involves being first to identify and access new technologies, competencies and knowledge from lead users in various markets, both internal and external to the firm's market or industry. The second is in the effectiveness and speed with which companies can connect these globally scattered pieces of knowledge and use them to create innovative products and services. The final stage is optimizing the efficiency of the global sales, distribution, marketing, and supply chain to leverage these innovations across global markets.

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<sup>20</sup> Santos, Doz, Williamson. From Global to Metanational: How Companies Win in the Knowledge Economy. Harvard Business School Press, 2001. p



Metanationals are different than multinationals in that multinationals will typically enter new global markets (either organically, or through acquisition/alliance) by simply projecting the knowledge-base and operations mind-set of their home markets. Metanationals, on the other hand, attempt to optimize the structures, processes, and incentives of the individual countries or regions, thereby leveraging the strengths and efficiencies of those countries to their full advantage. A remarkable example of metanationalism is illustrated by the Renault-Nissan automotive alliance.

One of the main reasons for the dramatic turnaround of Nissan and the success of the partnership was Carlos Ghosn's (current president & CEO of Nissan) ability to mobilize cross-functional and cross-cultural resources and strengths of the two companies in order to foster a culture of change through collaborative risk-sharing. Rather than walking into Nissan in 1999, which marked the eight consecutive year of losses for the Japanese automaker, and projecting the French company's processes and ideologies in a take-over fashion, Ghosn sought the more difficult strategy of finding a way to make changes while safe-guarding the identities and cultures of both companies. As a result, the alliance was successful in retaining the most beneficial and efficient aspects of each partner's culture: the efficient French management style with an incorporated U.S. business framework, and the Japanese manufacturing and quality expertise. As an interesting side note, all meetings from the inception of the alliance were spoken in English. The partnership is also "metanationally" efficient by sharing manufacturing capabilities in Renault and Nissan plants to optimize production of both families of vehicles.

By adopting the principles of Open Innovation, Lead User Process, Metanational Corporations, tier-one suppliers may discover new ways to create and capture value, and increase their chances of developing the breakthrough automotive systems dominant design, which has yet to emerge. The discussion now turns to the research conducted at ArvinMeritor, a tier-one supplier attempting to expand its capabilities from the realm of components to that of integrated systems.

#### **4. Innovation Research at ArvinMeritor**

The objective of this thesis was to explore value-creation and value-capture aspects of innovation, and to then apply the theories and concepts in a real-world context through case study research. This section poses the fundamental questions that guided the research, and discusses the research itself in terms of its scope, the framework for case selection, and the methodologies for data acquisition. As mentioned earlier, the research was conducted at ArvinMeritor, a company whose recent history reflects well the turbulent period of mergers and acquisitions that occurred in the automotive industry at the end of the 20<sup>th</sup> Century. The following is a brief introduction of this multinational tier-one supplier.

##### **4.1 ArvinMeritor, Inc.**

ArvinMeritor, Inc. is a \$7-billion global supplier of a broad range of integrated systems, modules and components to the motor vehicle industry. The company serves light vehicle, commercial truck, trailer and specialty original equipment manufacturers and related aftermarkets. In addition, ArvinMeritor is a leader in coil coating applications. The company is headquartered in Troy, MI, and employs 33,000 people at more than 150 manufacturing facilities in 27 countries.

Figure 4-1 illustrates the history of ArvinMeritor. Note that from 1997 to 2000, a combined six acquisitions took place, culminating with the mega-merger of the two suppliers. A description of the two legacy companies, Arvin Industries and Meritor Automotive (formerly Rockwell International - Automotive Operations), is provided below.

*Arvin Industries Inc.* established its reputation as a global manufacturer of automotive components and systems. Arvin consistently ranked as a leading manufacturer of automotive exhaust systems; ride and motion control products; air, oil, and fuel filters and gas-charged lift supports. Its products are sold under various trademarks including

Arvin, Maremont, Timax, ANSA and ROSI exhaust systems; Gabriel and RydeFX shock absorbers; Purolator filters and StrongArm gas-charged lift supports.

Meritor Automotive Inc. established its reputation as a global automotive supplier of a broad range of components and systems for commercial, specialty and light vehicle OEMs and the aftermarket. The Meritor product line consisted of two businesses: Commercial Vehicle Systems, a leading supplier of complete drivetrain systems and components for medium- and heavy-duty trucks, trailers and off-highway equipment and specialty vehicles, including military, bus and coach, and fire and rescue; and Light Vehicle Systems, a major supplier of roof, door, automotive body, access control and suspension systems, and wheel products for passenger cars, light trucks and sport utility vehicles.

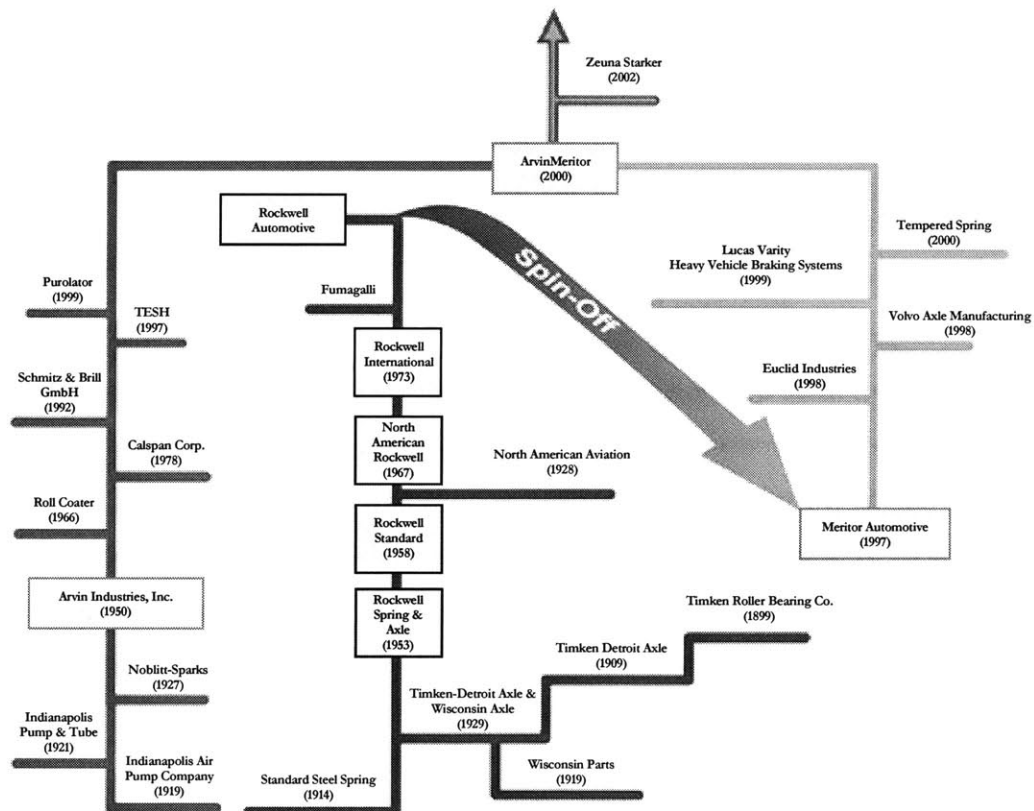


Figure 4-1: ArvinMeritor History

## 4.2 Scope of the Research

The scope of this research was designed to meet the requirements and timeline of an SDM master's thesis. While a significant research effort was put forth in exploring innovation strategies, and factors affecting profitability at ArvinMeritor, it is by no means exhaustive, but instead opens the door for additional work to be done. Areas of opportunity for continued research are discussed in Section 5.

The three sets of fundamental questions that guided this research are as follows:

- ♥ **SET 1:** What are the advantages of being first to market with an innovation?  
When does it pay to “wait and imitate”?
- ♥ **SET 2:** When does innovation pay?  
Is a great innovation, alone, enough to make money?
- ♥ **SET 3:** What are the critical factors that drive innovation profitability?  
Which factors, if any, are consistently present in profitable innovations, and which are consistently lacking or inadequately addressed in innovations that flopped?

While many of these questions may seem relatively straight forward, and their answers, in theory, not overly surprising, it was the insight gained from the application of the theories to innovations at ArvinMeritor that became most interesting. The first set of questions, *What are the advantages of being first to market, and when does it make sense to follow?*, is perhaps the most straight forward and was addressed in Section 2. The second set was touched upon also in Section 2, however is closely linked to the third set and will be explored further in this section.

In addressing the questions of *When does innovation pay?* and *What are the critical factors affecting innovation profitability?*, boundaries were drawn and assumptions were made to fit the scope of the research project. A list of factors thought to potentially contribute to

innovation success was generated based upon surveyed literature and knowledge gained from SDM coursework. The importance of these factors was then gauged through a series of interviews with key individuals involved in innovation development projects at ArvinMeritor. This list is presented in Table 4.1, with the factors grouped under seven

<b>Potential Factors Affecting Innovation Profitability</b>	
<b>Up-Front Planning</b>	<b>Product Development</b>
Identification of Customer Needs Idea Generation, Selection, Protection Customer vs. Market Focus	Internal Technical Competence Enterprise Collaboration Partnerships/Alliances/JV's, etc.
<b>Non-Product Related</b>	<b>Customer Switching Costs</b>
Depth of Customer Relationship Customer Service/Technical Support Product Availability Salesforce Marketing Technology Clockspeed Scalability	Training Costs Price Maintenance Costs Operating Costs Disposal Costs Implementation Costs Cost of Non-Quality
<b>Customer Perception</b>	<b>Business Model</b>
Highly Visible Benefits Useful Benefits Price per Performance Characteristics Supplier Image OEM Image	Value Proposition Value Chain Value Network Market Segment Cost Structure / Target Margins Competitive Strategy
<b>Product/Process/Service Differentiation</b>	<b>Table 4.1: Potential Factors Affecting Innovation Profitability</b>
Technology Functionality Distribution Technology "Readiness"	

main categories. Boundaries were established around the list, which is not intended to be all-encompassing, but rather a sampling of potential “heavy-hitters” in terms of their impact on profitability. In fact, it will be shown in Section 5 that some of the potential factors in the list turned out *not* to be factors at all, while others not on the list were found to be significant.

Definitions for each of these factors are listed in Appendix B, however one of the categories, the Business Model, which is often underutilized and in many instances neglected in large corporations, will be discussed here in greater detail.

### ***The Business Model***

In Section 2 it was supposed that proper alignment between value-creation (aspects of idea generation, product design & development, etc.) and value-capture (aspects of sales & marketing, business strategy, etc.) is necessary for an innovation to succeed. In Section 3.3, value-creation methods alternative to the traditional vertically integrated, closed innovation practices commonplace in the automotive industry were proposed, such as Chesbrough’s *Open Innovation process*, von Hippel’s *Lead User concept*, and Santos’ *Metanational theory*. Here, it will be supposed that a useful framework for capturing value from an innovation is represented by Chesbrough & Rosenbloom’s depiction of the business model.

The process of constructing a business model is useful in understanding how companies of all sizes can convert the technological potential of an innovation into economic value. Chesbrough argues that technology by itself has no single objective value. Moreover, the economic value of a technology remains latent until it is commercialized in some way, and the same technology commercialized in two different ways will yield different returns.

The business model in this context is defined by the following six functions:<sup>21</sup>

1. To articulate the *value proposition*, that is, the value created for users by the offering based on the technology
2. To identify a *market segment*, that is, the users to whom the technology is useful and the purpose for which it will be used
3. To define the structure of the firm's *value chain*, which is required to create and distribute the offering, and to determine the complementary assets needed to support the firm's position in this chain
4. To specify the revenue generation mechanism(s) for the firm, and estimate the *cost structure* and *target margins* of producing the offering, given the value proposition and value chain structure chosen
5. To describe the position of the firm within the *value network* linking suppliers and customers, including identification of potential complementary firms and competitors
6. To formulate the *competitive strategy* by which the innovating firm will gain and hold advantage over rivals.

The more time spent discovering an appropriate business model, the better the firm's chances are of unlocking the maximum potential value in a new innovation.

Cognitively, the business model can be thought of as a mechanism for bridging the technical and economic domains of an innovation (Figure 4-2). Chesbrough describes one situation utilizing such an intermediate linkage: While technical managers may not understand the benefit to consumers from increasing the capability and performance

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<sup>21</sup> Chesbrough, Henry. *Open Innovation*. 2003. Chapter 4.

of their technology, they may be able to comprehend how their decisions will impact a defined value proposition to a chosen group of customers; and marketing managers will not know the preferences of their customers on many technical topics, but will have a good idea of how specific improvements in the value proposition can be converted into higher prices, greater market shares, and greater profits. The realization of economic value from an innovation is, in this context, driven by the defined attributes of the business model, rather than by some inherent characteristic of the technology itself.

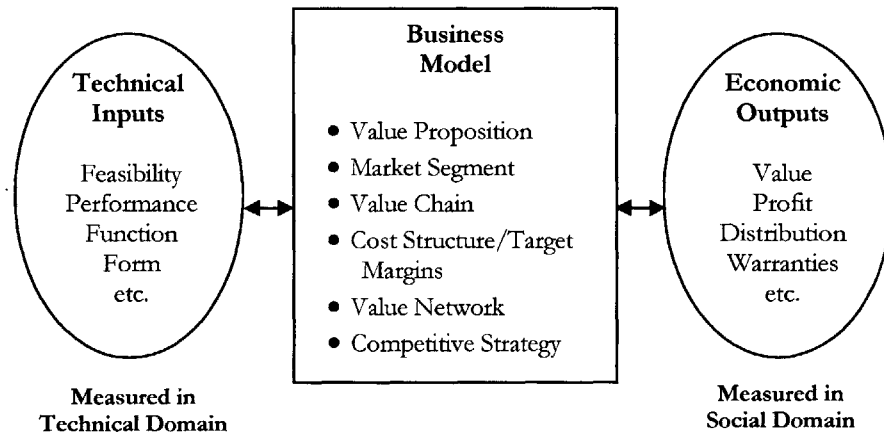


Figure 4-2: The Business Model as a Cognitive Map Across Domains (Source: *Open Innovation, Chesbrough*)

### 4.3 Innovation Case Selection Framework

The framework used to select innovation case study subjects is depicted in Figure 4-3. A two-by-two matrix was constructed, with the Business Driver along the horizontal axis, and Profitability along the vertical axis. Innovations were first categorized based upon the program’s prominent business driver, i.e. whether saving money or providing new customer features was the main impetus. Next, they were categorized based upon whether or not they were profitable. The innovation selections were not limited to new



products; process innovations in the areas of manufacturing, logistics, procurement, etc. were also considered. The objective of this approach is to determine the following:

- ✦ What common factors, if any, are exhibited (or lacking) by innovations within the same quadrant?
- ✦ What factors are common among all successes (i.e. Q1 & Q2) and what are common among all failures (i.e. Q3 & Q4)?
- ✦ Are there any discriminating factors between successes and failures? Was something lacking in the failures that was deemed critical to the successes?
- ✦ Do the critical factors for success of component or module-based innovations also apply to more complex systems-based innovations?

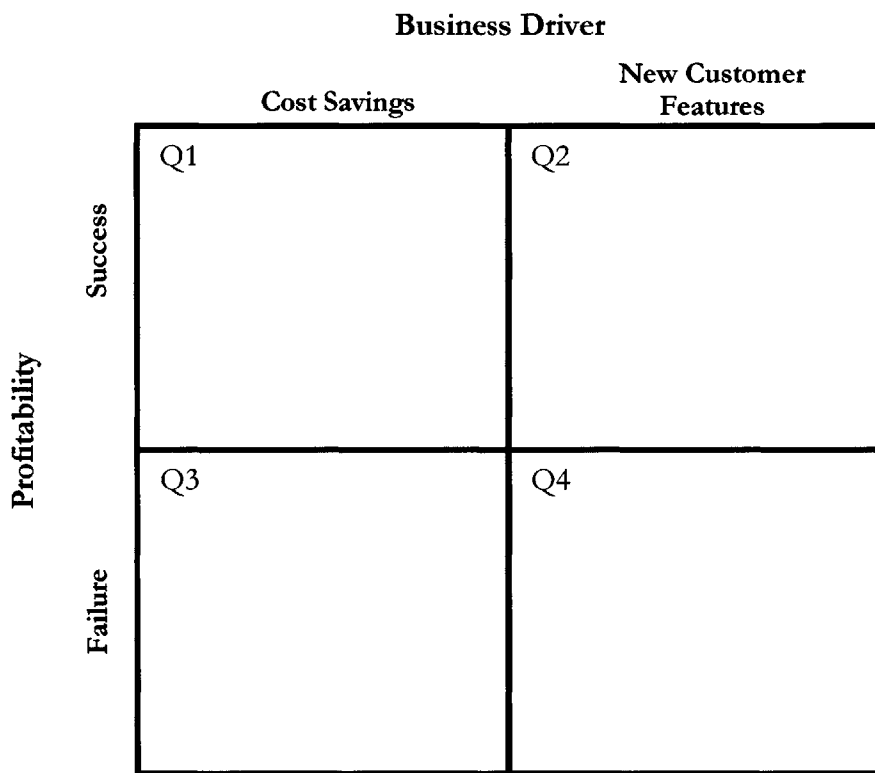


Figure 4-3: Framework for selecting innovation research cases

The first three bullet point questions listed above are collectively designed to answer the fundamental question of “What matters most?” in terms of profiting from innovation. The last bulleted question addresses the possibility that factors critical to the success of component-based or module-based innovations may be different than those of system-based innovations. Only three of the eleven innovations researched were classified as systems. This is largely due to the fact that ArvinMeritor has historically been a component supplier, and has only recently entered the integrated systems market. Also, while there are currently integrated system designs in various phases of ArvinMeritor’s development process, they have not yet been commercialized and therefore do not meet the profitability criteria of the selection framework. Figure 4-4 illustrates the framework filled in with the selected innovation case studies. The cases in blue font indicate systems-based innovations.

		Business Driver	
		Cost Savings	New Customer Features
Profitability	Success	<b>Q1-1:</b> <i>Axle Shaft Process Innovation</i> <b>Q1-2:</b> <i>Customer Value Centers</i>	<b>Q2-1:</b> <i>RHP-11 Highway Parallelogram System</i> <b>Q2-2:</b> <i>Low-Floor Axle</i> <b>Q2-3:</b> <i>LFI Composite Roof Module</i>
	Failure	<b>Q3-1:</b> <i>ZF-Meritor Single Rail Top Cover</i>	<b>Q4-1:</b> <i>Hydraulic Self-Leveling System</i> <b>Q4-2:</b> <i>Anti-Squeeze Window Regulator</i> <b>Q4-3:</b> <i>Al Carrier</i> <b>Q4-4:</b> <i>VST Shock</i>

Figure 4-4: ArvinMeritor Innovation Cases

#### **4.4 Research Methodology**

The data acquisition for this research was primarily accomplished through a series of interviews conducted with ArvinMeritor personnel who were closely involved with the selected innovation projects. Interviews were used as a tool to capture the often tacit details of how a project team navigated through the “fuzzy front end” of an innovation. Over 20 interviews were conducted with corporate officers, executive vice-presidents, business unit general managers, chief engineers, and project engineers to gain, in many instances, multiple perspectives on the factors driving innovation success or failure in each of the case subjects. Discussions focused on the list of potential factors from Table 4.1, while probing for details revealing other factors that may have had significant influence on the final outcome. Views on ArvinMeritor’s new integrated systems initiatives were also discussed. The results presented in Section 5 are based on the author’s interpretation of the details and data collected from the interviews. In most instances, the interview data in case-format was reviewed by the interviewees for approval before conclusions were drawn.

### **5. Results, Discussion, & Conclusions**

In this, the concluding section, results from the various interviews will be presented in the form of factors identified to be significant in the outcome of each ArvinMeritor innovation project. Discussion of these results will follow, focusing on the extraction of the critical innovation success factors. The implications that the data has on critical success factors for complex system design will then be illustrated in a framework to show the interdependency that exists among the value creation and value capture aspects of systems-based innovations. Finally, conclusions will be drawn from the research, and opportunities for further research will be discussed.

#### **5.1 Results**

Results from the research interviews are presented in Table 5.1. Along the top of the table are the various innovation cases, grouped within their respective framework

quadrants Q1-Q4 from Figure 4-4. For instance, innovation #1 under heading Q1 represents innovation case Q1-1, or the Axle Shaft Process Innovation. Similarly, innovation #3 under the heading Q4 represents innovation case Q4-3, or the Aluminum Carrier innovation. The various potential factors from Table 4.1 are listed down the first column. As was mentioned in the previous section, the purpose of the interviews was to extract the factors that significantly contributed to the ultimate outcome of each innovation. The findings are represented in the table with the use of two colors. The green cells indicate those factors that contributed to the success of the profitable innovations in quadrants Q1 & Q2, while the red cells indicate those factors that contributed to the lack of success of the innovations in quadrants Q3 & Q4. Cells that were left blank indicate that the factor was not found to have any significant impact on innovation profitability, or lack thereof.

A red cell means that it was either explicitly stated in the interview or implicitly inferred from the interview data that the factor was inadequately addressed, inaccurately assessed, or missed altogether. In a similar fashion for the greens, it was concluded either explicitly or implicitly from the interviews that the factor positively impacted the success of the innovation. For example, the cell for the factor *Highly Visible Benefits* in the Axle Shaft Process Innovation case (Q1-1) was colored green because the interviewee explicitly stated that OEM customers could plainly see the benefit of longer fatigue life with the new low-frequency induction hardening process. However, while it was not explicitly stated that the *Value Chain* was a contributor to the success of the process innovation, this cell was also colored green because it was gathered through the interview that the team realized they needed to collaborate with an induction hardening coil-design specialist to create a coil that would handle the intense heat generated by the lower induction frequency. Therefore, by determining the complementary assets needed to support the firm's innovation, ArvinMeritor adequately addressed the *Value Chain* factor.

Framework Quadrant	Q1		Q2			Q3	Q4			
	1	2	1	2	3	1	1	2	3	4
<b>Innovation</b>										
<b>Up-front Planning</b>										
Identification of Customer needs							■		■	■
Identification of Customer DMU							■			
Idea generation, selection, protection										
Customer vs. Market focused (vice versa)							■		■	■
Partnerships/Alliances/JV's etc.								■		
<b>Business Model</b>										
Value Proposition							■		■	■
Value Chain							■			
Value Network										
Market Segment							■			■
Cost Structure & Target Margins							■		■	
Competitive Strategy								■		■
<b>Non-Product Related Attributes:</b>										
Depth of Customer Relationship										
Customer Service/Technical Support										
Product Availability (delivery speed & reliability)										
Salesforce										
Marketing (advertising, price, promotion)							■		■	
Technology Clockspeed										
Scalability (market size)										
<b>Product/Process Differentiation</b>										
Technology										
Functionality										
Distribution										
Technology "Readiness"										
<b>Customer Perception</b>										
Highly visible benefits							■	■		■
Useful benefits (satisfy a need, solve a problem)									■	■
Price/Performance Characteristics										
Supplier Image										
OEM Image										
<b>Product Development</b>										
Internal Technical Competence									■	
Enterprise Collaboration							■			
Schedule Pressure										
Identifying System-level Requirements							■			
<b>Customer Costs (switching costs)</b>										
Training Costs										
Price										
Maintenance Costs										
Operating Costs										
Disposal Costs										
Implementation Costs ("ilities")										
Cost of Non-Quality (warranty, field issues)							■			

Table 5.1: Innovation Research Results

An example on the red side is the Aluminum Carrier, innovation Q4-3, which experienced dismal market performance largely due to its high price tag. As one interviewee put it, “we were so focused on the market driver calling for reducing weight in the trucks to improve fuel efficiency that we produced the aluminum carrier without really understanding what our customers would actually be willing to pay for it.” From this information, the *Customer vs. Market focus* factor was colored red, as well as the *Value Proposition* and *Price/Performance Characteristics* factors. The interview data in this case revealed the fact that ArvinMeritor only partially identified the needs of the customer. While the expensive, but lighter weight carrier met the need for weight reduction, it conflicted with another major initiative of the OEM -- reduce vehicle cost. For this reason, the *Identification of Customer needs* factor was colored red. Explanations of these sorts are not provided for each colored cell in Table 5.1, however the same thought exercise was conducted for each. In all cases, attempts were made to prevent personal biases from entering into the analysis by basing the coloring of cells solely upon interview statements and facts. In many cases, second interviews were conducted and/or follow-up questions were posed to clear up uncertainties or inconsistencies in the data.

## 5.2 Discussion

Looking at Table 5.1 might beg the questions, *So What? What do all of these colored squares tell us?* The research data was presented in this way to help identify what went right for the profitable innovations (referred to herein as *successes*), and what didn't go right, or was missing from the non-profitable ones (referred to herein as *failures*). It was thought best to begin analyzing the data by taking a holistic view of Table 5.1. This was done by literally standing five to ten feet away from the table and simply looking at the interesting clusters of colored cells that emerged from the data. It was observed that for the successes, green-cell clusters appeared in six out of seven factor categories, while red-cell clusters for the failures appeared in only three categories. Next, and perhaps more importantly, it was observed that a few of the line item factors were colored green for nearly all successes and *also* were colored red for nearly all failures. These two points

were examined in further detail by revisiting the questions asked in section 4.3 regarding common factors among successes and among failures, and discriminating factors between successes and failures.

### ***Successes***

The first factor in Table 5.1, Identification of Customer needs, was marked green for all successes. It was clearly evident from the interviews that these innovations succeeded in meeting the needs of the customer. For example, the axle shaft process innovation met the customers' needs for improved performance and reduced overall cost; the customer value centers (CVC) answered the call for reduced delivery risk, lead time, and OEM manufacturing costs via the closely located tier-one subassembly facilities.

Closely related to identifying customer needs is articulating the value proposition, or the value created for the customer by the offering. Each of the successes expressed a value proposition for the innovation. The *low-floor axle*, for example, offered city bus travelers the ease of entering and exiting the vehicle without climbing steps, accomplished by creating a drive axle assembly that accommodates a lower vehicle passenger floor. In fact, the large clustering of green cells in the Business Model section of Table 5.1 illustrates that nearly all elements of the business model were addressed, in some cases intentionally and in others indirectly, and were expressed in hindsight as being significant contributors to the success of the profitable innovation projects.

Other common factors among the successes appeared in the Customer Perception section, where all innovations offered both *highly visible* benefits as well as benefits perceived by the customer as *useful*. The composite roof module's enhanced strength and rigidity, for example, was demonstrated to OEM's with dramatic flair, as the ArvinMeritor sales representative would lay the roof module on the ground and proceed to jump up and down on it trampoline-style without making a dent.

Finally, nearly all successes were effective in breaking down barriers associated with switching costs, such as the reduced OEM maintenance costs offered by the RHP-11 integrated air suspension and braking system, or the reduced OEM operating and training costs associated with the Customer Value Centers (CVC).

### ***Failures***

Clusters of red cells were found in the Up-front Planning, Business Model, and Customer Perception sections of Table 5.1. Half of the failed innovation interviews reported that customer needs were inadequately identified, which severely impacted the success of the program. Interestingly, another Up-front Planning factor that was found to have a significant negative impact on only these same three innovations was Customer vs. Market focus. In the case of the Hydraulic Self-Leveling System (Q4-1) in the early 1980's, the focus was centered on introducing a new technology to the passenger car market, unfortunately without realizing that passenger car owners at that time were not using their vehicles to haul heavy loads. Because customers did not perceive this new feature as being valuable, they did not elect to purchase the option on their new vehicles. Twenty years later however, there is a large consumer market for self-leveling systems due to changes in how the passenger car is used today. The technology is very popular in markets such as minivans which are used for a wide array of tasks, from car-pooling children to soccer practice or hauling do-it-yourselfer's home improvement materials, to pulling a large boat to the lake.

The VST Shock innovation (Q4-3) had the opposite problem. The innovation was targeted to address the needs voiced by North American consumers to improve driver comfort – and it did just that. Drivers could feel a real improvement in ride “softness” with the new shock, and the product proved to be very successful. The problem arose when the investment was made to launch the innovation in the European market. As production rolled out and European vehicles were equipped with the new shock, drivers complained that the vehicle did not *feel right*. The product performed miserably.



ArvinMeritor was so focused on the technology's acceptance by North American customers that it failed to realize that Europeans preferred a "stiffer" ride.

### ***Identifying Criticality through Discriminating Factors***

While Table 5.1 illustrates a number of factors that were identified through the research interviews as significant contributors to the profitability performance of each innovation, the ultimate objectives of the research were to identify those factors that are *most critical* to an innovation's success, and to determine their implications on complex system-based designs. Critical factors were identified by locating within the various clusters (i.e. factors present in many innovations) those factors that heavily discriminated between successes and failures. By identifying which factors were instrumental in both positively impacting the successful innovations, *and* negatively impacting the failed innovations, management can focus on sufficiently addressing these factors in the development of new products.

The critical factors extracted from Table 5.1 are shown in Figure 5-1. The densest clusters of discriminating factors appeared within the *Business Model* section. Indeed, the successful innovations were found to have addressed the aspects of the business model much more so than did the failures. Rather than treating the six functions that make up the Business Model as individual factors, they will be collectively regarded as one critical core attribute for innovation success. The Business Model is considered here to be the "rudder" that essentially navigates the innovation through the various concept and product development stages.

Of the three other identified critical elements for success, identification of customer needs, highly visible benefits, and useful benefits, the first can be thought of as being an upstream process flowing into the business model, while the latter two are downstream results flowing out of the product development process. *Identification of customer needs* was

found to be a critical exercise that must occur in the very early, or initial upstream stages of concept development. The knowledge gained from this process is used to drive the

Business Model	Identification of Customer Needs
Highly Visible Benefits	Useful Benefits

Figure 5-1: Critical Innovation Success Factors

value creation and value capture aspects of the firm's innovation process. What ideally emerges from the firm's innovation process is a concept design that flows into the development process, ultimately resulting in a product, process, or service that satisfies the two remaining identified downstream critical factors, creating both *highly visible* and *highly useful* benefits for the customer or end user. This idea is conceptually illustrated in Figure 5-2.

This is not to say that other factors such as *technology*, *internal competence*, and mitigation of *customer switching costs* were not found to be significant; on the contrary, it was stated in the interviews that these factors were extremely important in the ensuing profitability of the successful innovations. However, it was felt that success in these areas was manifested through the accurate identification of customer needs and thoughtful creation of a business model. In the case of ArvinMeritor's Specialty Axle division, which drove the low-floor axle innovation, the business unit approaches every new product design by first conducting what they refer to as "Customer Engineering". This is a rigorous practice of interacting with the customer to identify their needs, thereby gaining a clear understanding of the application intended for the product. The team will even

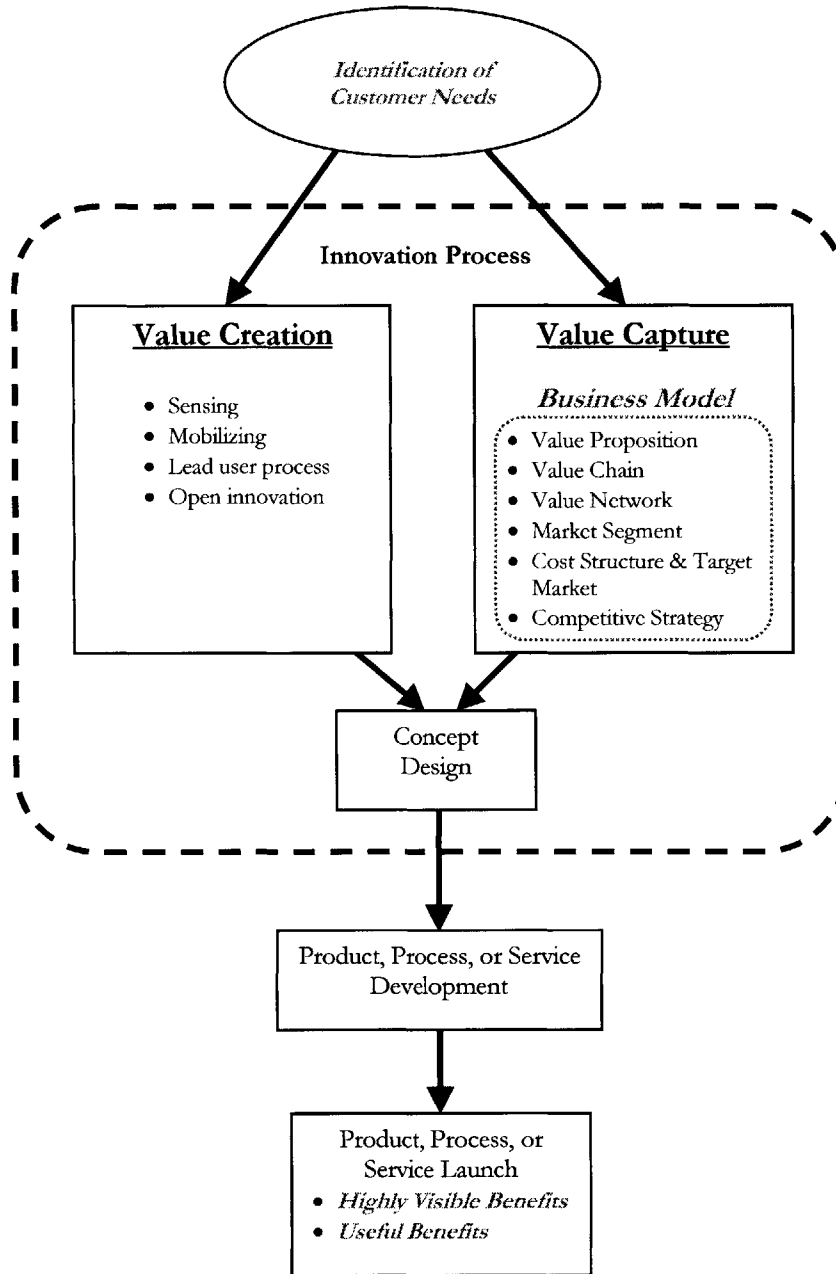


Figure 5-2: Placement of critical factors in a simplified, conceptual development process

instrument a customer vehicle to acquire valuable duty cycle information allowing them to identify where modifications could be made to optimize the performance of the existing design. The goal of this process is to gain a deep understanding not only of the stated customer needs, but also the “unspoken needs” that lead to differentiated products

and customer delight. “In this instance,” remarked Pedro Ferro, vice president and general manager of the Specialty Axle division, “it is important to be first to market in order to build barriers to entry and drive profits longer.”

A sound understanding of the customer’s needs facilitates the creation of the value proposition, and helps to identify the technology required to meet those needs, what complementary assets are needed from outside the firm, the target market segment, and so on, until a clearly defined business model is formed. By successfully addressing these upstream processes, the subsequent development processes are likely to be more efficient, and the goal of producing highly visible and useful customer benefits is more likely to be met.

### **5.3 Implications of Critical Factors on Complex System Innovations**

The final objective of the research was to place these critical factors specifically in the context of more complex, system-based innovations to determine if these same factors are applicable, and if others might apply. Although only three of the innovation case studies were considered to be system designs (Q2-1, Q3-1 & Q4-1), the topic of systems was discussed in all interviews, and some very interesting insights were gained from the data and from interview comments regarding what is needed for ArvinMeritor to excel as a systems integrator.

Since the critical factors described above were extracted from all of the data, systems innovations included, it was logical to conclude that the factors were applicable to systems innovations specifically. The critical factors are considered fundamental criteria that should be addressed for innovations regardless of their complexity. Looking at only the three systems innovations in the study, Q2-1 and Q4-1 exhibited discriminating factors in the four critical areas of Figure 5-1. Q3-1 however, was a bit of a different animal. This innovation program set out to redesign an existing commercial vehicle transmission to address identified customer needs of reduced cost and weight, and to

address internal manufacturability issues regarding assembly efficiencies and ergonomics. While customer needs and many of the business model attributes appeared to be adequately addressed, what led to the demise of this program was the internal product development process that was subjected to intense schedule pressure to launch simultaneously with a new noise-reducing transmission auxiliary box, and to “catch up” to a competitor’s recent launch of a lighter-weight and less expensive transmission. Therefore, the team attempted to reduce development time by retaining as many legacy elements as possible and shortening validation and field testing phases. What ultimately occurred was a reduction in assembly complexity (as planned), however at the expense of dramatically increased complexity in the shifting mechanism. Emergent behavior occurring between interactions of the legacy elements with the new shift bar design resulted in an unanticipated bending stress on the shift bar, causing fractures to occur typically within the first year of service.

As a result of the transmission case study, two additional factors were placed in Table 5.1. The first was *schedule pressure*, which directly led to the shortened development cycle and consequent field fractures, and the second was a more deep-rooted concept that emerges with increasing design complexity, which was referred to as *Identifying System-level Requirements*. System-level requirements consist of a quantifiable means of describing how various components, assemblies, or modules must perform together as one integrated system, and an understanding of how this system interacts with surrounding systems. As a component supplier, validation would typically require component dimensional, physical, and mechanical property verification, as well as a series of component cyclic durability tests. Any interactions on a system-level would occur only in field testing, near the end of the product development process. An upstream process is needed to proactively identify and understand the system-level interactions at the concept design stage rather than reacting to emergent behavior during field testing in final validation.

The identification of system-level requirements turned out to be only one of a number of new competencies needed to be the leader in the integrated systems arena. It was clear from the interviews that ArvinMeritor's transformation into a systems supplier requires a broader range of system skills, and a fundamental cultural shift from component-level thinking to "systems-thinking". While cultural change is acknowledged as an extremely important ingredient to the overall transformation, the topic is beyond the scope of this research. This discussion will instead focus on the factors (processes and competencies) deemed critical for a systems supplier, based on literature, interview data, and course studies, and represented by the integrated framework shown in Figure 5-3.

The framework illustrates the design of a system-based innovation with the use of two interdependent wheels, which require the momentum gained by addressing the critical inputs of each wheel to keep the other in motion.<sup>22</sup> The wheels represent the architectural foundation of the system. The wheel on the left encompasses the value creation or **System Architecture** side, with the wheel split into three sections denoting the fundamental architectural principal of "*function maps to form through concept*".<sup>23</sup> The wheel on the right encompasses the value capture or business model side, which is referred to here as the **Revenue Architecture**.<sup>24</sup> The six functions of the business model are contained within this wheel.

The four critical inputs driving each wheel were extracted from literature research, coursework, and through interviews, which included discussions of the three systems innovation case studies as well as corporate strategy issues related to systems integration. Conceptually, if inputs to one wheel are inadequately addressed, then the speed of both

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<sup>22</sup> The framework in Fig. 5-3 is an enhancement of Ed Crawley's System Architecture framework, which is shown in Appendix B

<sup>23</sup> Crawley, Ed. System Architecture lecture, September 2002.

<sup>24</sup> Chesbrough & Rosenbloom, "The Role of the Business Model in Capturing Value from Innovation," *Industrial and Corporate Change* II, no. 3 (2002): 529-556.

wheels will decrease, thereby lowering the potential success of the innovation. The inputs to each wheel are discussed below.

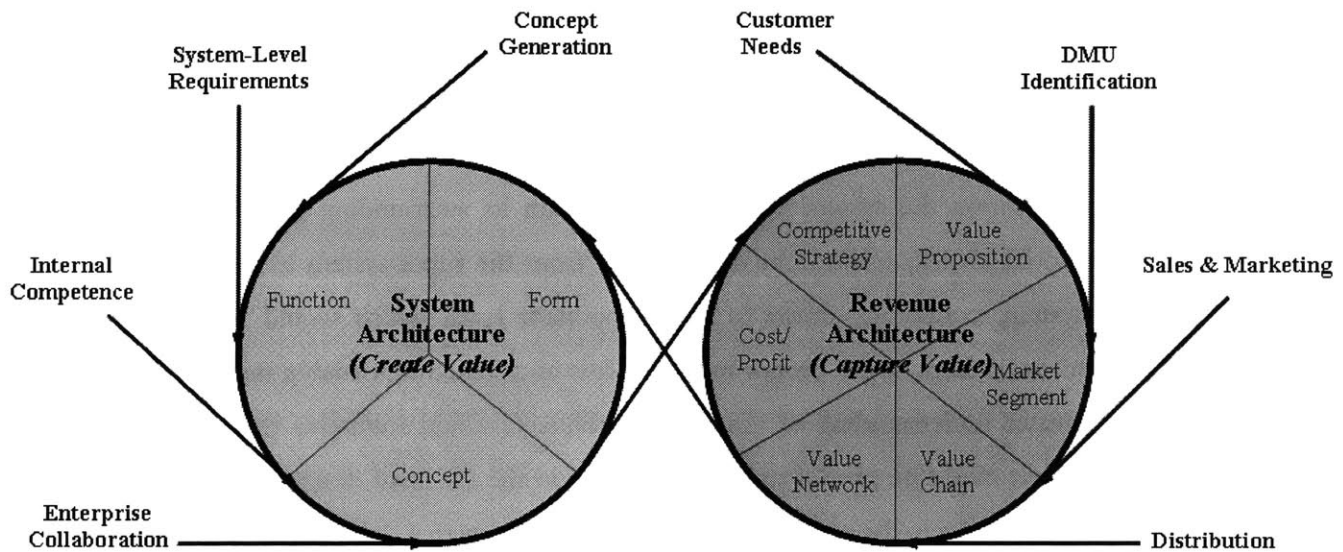


Figure 5-3: Framework for Systems-Based Innovations

### System Architecture Wheel (Creating Value)

#### *Concept Generation*

Concept generation represents a critical aspect of a firm’s innovation process that facilitates the creation of breakthrough products, processes, and services. The traditional inward-focused practice of developing technologies and products solely in-house is obsolete. In today’s knowledge economy, the firm must realize that useful information and technology is abundant in many industries and countries, and it must therefore compliment its internal idea-generation activities by developing the capability to seek out the disparate global pockets of technology (referred to earlier as *sensing*) and learn how to apply it to the creation of new breakthrough concepts. This paper cited tools such as the

Lead User process, Open Innovation, and the Metanational theory to aid in innovating the concept generation process.

### ***System-Level Requirements***

The importance of identifying system-level requirements was discussed above, and will be a critical ingredient of successful systems design. A systematic upstream process is needed to facilitate the proper creation of product form based on the interfaces and interactions within the system itself, as well as with its surrounding systems. Such a process would identify a hierarchy of functions from the super-system to the system to the subsystem, continuing down to the component level, which would facilitate the development of form in the proper manner. It is anticipated that such a method would yield a greater understanding of the system architecture and minimize the number of functions that might be missed or misunderstood in the up-front design process, which consequently results in the rework and unplanned iterations that delay programs.

### ***Internal Competence***

The level of thought expansion required to develop systems-based competencies must be reached by a critical mass of a firm's employees, widespread throughout the corporation in functions ranging from engineering to marketing to procurement. Training engineers only is not enough, since it does the firm no good, for instance, to develop an elegantly integrated system that does not sell because the sales force cannot communicate the systems-based value proposition to the customer.

Another key aspect of a systems-based growth strategy is the development of a critical mass of *systems engineers* to help facilitate the commercialization of systems-based innovations. This relatively new breed of engineer is an invaluable resource in bridging the gap between concept and commercialization due to their acquired skills in thinking holistically about the entire product life cycle in terms of concept, design, implementation, operation, product & process, risk management, and sustainability.



System engineers are not generalists, but specialists in simplifying complexity, resolving ambiguity, and focusing creativity. They play key roles in architecting complex products by defining system boundaries, goals, and functions, anticipating failure modes, planning for mitigation and recovery, and defining and managing subsystem interfaces. In addition, a valuable attribute of systems engineers is their ability to serve as *language translators* between the various disciplines involved in cross-functional development projects. For example, the breadth of a systems engineer's training allows her to speak "*marketing*" with the marketing personnel in terms of customer needs, distribution and pricing strategies, etc., and translate that information into system design goals and technical specifications required by engineering, while her understanding of operations strategies can aid in mediating between manufacturing and procurement to formulate an appropriate make-buy strategy. Status updates of the project can then be communicated to upper management using the financial and management terms that this group is accustomed to. This skill set alone can significantly improve development efficiencies by removing organizational barriers and allowing streamlined unambiguous communication, improved coordination, and reduced development rework.

Competencies must also be enhanced in the areas of systems-based design, computer simulation & modeling, and validation testing at the systems level. Rapid-exchange of design information throughout the supply chain is critical for developing efficiencies in design, simulation, and validation. Continuing software advancements in 3D manufacturing simulation, real-time web-based supply chain design interaction, and dynamic safety, durability, and reliability modeling, provide potentially powerful tools to help reduce uncertainty and streamline the development process. The value from these tools can only be realized through the development of strong supply-chain collaborative partnerships, which is discussed next.

### ***Enterprise Collaboration***

*“The competitive and technological challenges that face manufacturers in the future demand that they operate in a broader, more holistic context. No company can succeed by itself. Those that try to do it alone may not survive.” – William Hanson, The Integrated Enterprise*

In order for a firm to be successful in its systems development initiative, it must work to integrate the various internal and external stakeholders (i.e. sales, marketing, engineering, manufacturing, suppliers, research centers, customers, etc.) into a cohesive *enterprise* with a common focus of capturing and delivering value. The impetus behind the theory that an enterprise approach to product development is needed for sustainable success comes from the on-going research being conducted by the Lean Enterprise Initiative (LEI) group at MIT. The LEI presupposition that organizations must look outward as well as inward to realize and deliver value is very complimentary to the concepts behind *open innovation*. Here we will address one critical aspect of lean enterprise integration - the importance of early supplier involvement for efficient product innovation and development.

Innovations in product architectures may be gained through early supplier involvement by leveraging and benefiting from supply-chain expertise and tacit knowledge to further exploit the existing technology and to aid in the development of new technology. The process of early supplier involvement is characterized by shared responsibility within the customer-supplier design team, and should be made unconstrained by enacting contractually-agreed-upon workshare arrangements. In addition, proper incentive structures are needed, involving long-term relationships, and motivations to share both risks and gains. The common incentivized practice among most tier-ones today of solely awarding business to the lowest bidder in order to meet mandated cost-savings targets (often driven by OEM's) is counterproductive to the enterprise approach, and must be changed. Furthermore, in order to truly realize the benefits of early supplier involvement, the initiative must be driven top down, communicating the importance of coordinating efforts with strategic suppliers as a means of achieving customer and shareowner value

through product quality, reliability, and functionality, with cost contributing to, but not dominating, the supplier selection process. A realignment of incentives and processes must occur if this strategy is to be effectively implemented.

### **Revenue Architecture Wheel (Capturing Value)**

#### ***Identification of Customer Needs***

This input is perhaps the most critical and has been discussed extensively in the paper. However, an interesting complexity arises with respect to customer interaction when developing system-based products. This complexity is related to the firm's need to address a larger body of customer stakeholders, which is an important distinction from component-level sales and marketing and is discussed below as a separate input.

#### ***Identification of Customer DMU***

Just as the complexity increases from component-based to systems-based products, the required interaction with the customer also increases in complexity, due to the value proposition of the system affecting multiple customer stakeholders. As the integrated system typically addresses needs from multiple players within the customer organization, it becomes important to identify what parties are involved in making the purchasing decision; who are the *gate-keepers*?, who are the *influencers*?, who are the *vetoers*?, and who can sign on the dotted line?. In other words, it is critically important to determine who comprises the *decision making unit (DMU)*.

#### ***Sales & Marketing***

This input encompasses the other two identified critical needs from the research: *highly visible benefits* and customer-perceived *useful benefits*. While the value proposition and other business model functions set the stage for the development of a valuable product offering that addresses customer needs, the role of the Sales and Marketing functions are critical in both communicating the needs of the customer to the engineering community, and communicating and demonstrating the product's value to the customer. The Sales &

Marketing division must also keep in close contact with the firm's internal customers such as its lobbyists in Washington, to remain current on upcoming government standards and regulations that may impact the firm's industry or create a changing customer need. While it rarely occurs in organizations today, a sales or marketing representative should be involved in the firm's innovation process during the concept generation phase, as this person should hold the most in-depth customer knowledge. Finally, the sales force must educate the DMU, as stated above, about all of the obvious and ancillary benefits provided by an integrated system.

### ***Distribution***

The role of the tier-one systems-integrator brings with it the added responsibility to maintain control over the entire supply chain. This requires tier-ones to have clear and complete supply chain visibility and to foster greater collaboration with its sub-suppliers to optimize subsystem integration and streamline distribution operations. A strategy that has thus far been successful for ArvinMeritor is the creation of Customer Value Centers (CVC) located in close proximity to customer final assembly plants. CVC's act as integration houses, where ArvinMeritor manufacturing plants and sub-suppliers send their components and modules to be integrated into one complete module or subsystem, which is then delivered to the customer. The benefits to the customer include lower delivery risk by significantly reducing the number of shipping lanes, shortened freight time, and reduced working capital, inventory, and part numbers. Similar initiatives are being pursued by OEM's who are creating "supplier parks" or "supplier manufacturing campuses", which are enormous industrial supply chain centers located typically within a mile or so from the OEM assembly plant. Suppliers must continue to innovate in the area of supply chain management, as OEM pressures in this area are not likely to cease, especially with the advent of consumer internet ordering and migration toward mass-customization. Indeed, innovations in supply chain management and distribution should be held with as high a regard as product or process innovations.

## 5.4 Conclusions

North American automotive OEM's continue to evolve their business strategies in a struggle to reclaim their declining market shares from foreign counterparts. In a desperate attempt to buy back market share and grow their bottom line, OEM's have instituted drastic cost-cutting measures through outsourcing, slashing their supply base, mandating year-over-year supplier price reductions, and continually extending an already prolonged 0% financing incentive program. As a result, demands placed on tier-one suppliers have increased, competition throughout the supply-chain has intensified, and new strategies for sustainability are needed. The myriad engineering, development, and validation responsibilities passed down by OEM's have resulted in the formation of a "new" first tier – the systems integrator. The transition from components to integrated systems and modules has definite implications on the firm's innovation and product development processes. This paper has focused on supplier innovation strategies, arguing that the predominately inward-focused or *closed* innovation approach traditionally taken by vertically integrated corporations, such as those widespread throughout the automotive industry, has become obsolete. Suppliers must realize that innovative ideas are not scarce, but rather are abundant and widespread across many of today's global industries. Three concepts (Open Innovation, Lead User Process, and Metanational Corporations) were introduced as techniques for suppliers to *innovate* their innovation processes.

It was further argued in the thesis that proper alignment between value creation and value capture aspects of an innovation are required to maximize its profitability potential. Research conducted at ArvinMeritor, a tier-one supplier entering the integrated systems domain, explored predominately the value capture aspects of automotive innovations. Ten ArvinMeritor product, process, and supply-chain innovations were examined in attempt to determine what critical factors had the most impact on profitability. The results were then placed in a systems context to understand whether concentrating on

these factors is sufficient for ArvinMeritor to excel in its pursuit of maximum profitability potential of systems innovations.

Four main factors stood out from the research as being critical to the success of any innovation:

- ✦ Identification of **Customer Needs**
- ✦ Creation of an Innovation **Business Model**
- ✦ Creating customer-perceived, **highly-visible benefits**
- ✦ Creating customer-perceived, **useful benefits**

These factors were thought to have significantly contributed to the profitability of the successful innovations, and were either inadequately addressed, inaccurately assessed, or missed altogether in the failed innovations. The Business Model was considered a critically core attribute of successful innovations, and consists of six main functions: *Value Proposition, Market Segment, Value Chain, Cost Structure/Target Margins, Value Network, and Competitive Strategy*. Adequately addressing these aspects of the business model, as well as the other three identified critical factors from the research, was found to have a compounding affect on the overall success of the profitable innovations. When these factors were addressed, a clearer path forward was established in terms of technology, product development efficiency, communication, etc.

When applied to systems innovations, however, insights gained from the interviews suggested that the critical factors listed above are necessary, but not sufficient. The role of the systems integrator requires the firm to acquire new skill sets and competencies in order to create and capture value from systems-based innovations. A framework conceptualizing the perceived critical inputs to the systems innovation process was presented. This framework consisted of two rotating wheels, System Architecture (value creation) and Revenue Architecture (value capture), with the momentum of each wheel

needed to keep the other moving. The interdependent inputs to each wheel were as follows:

**Systems Architecture** (value creation)

- ✦ Concept Generation
- ✦ Identification of System-Level Requirements
- ✦ Internal Competence
- ✦ Enterprise Collaboration

**Revenue Architecture** (value capture)

- ✦ Identification of Customer Needs
- ✦ Identification of the Decision-Making Unit (DMU)
- ✦ Sales & Marketing
- ✦ Distribution

The cases studies and interviews suggest that ArvinMeritor typically employs a second-mover innovation strategy. The benefits of such a strategy include reduced market uncertainty, as well as reductions in product design and development expenditures. The risks, however, include a potential loss of credibility, and share price, from customer and investor perception of being a product and technology *imitator* or *follower* rather than a technology *leader*, and allowing the competition to enjoy a temporary monopoly, as well as the opportunity to build strong brand loyalty. Furthermore, playing “catch-up” to the competition typically results in excessive schedule pressure to develop and launch the product as quickly as possible. This can have the opposite intended effect, since increased schedule pressure has been shown to increase rework generation, resulting in unplanned iterations that lead to project delays, or even worse the potential for defective products in the field that can lead to messy warranty recall campaigns.<sup>25</sup> Finally, the second-mover strategy is not well-suited for generating breakthrough product concepts,

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<sup>25</sup> Lynceis, Jim. Dynamics of Project Performance, MIT Lecture, September 26, 2002.

and is predominately focused on near-term returns. Therefore, the continued use of this strategy will not allow the firm to achieve market leadership in the integrated systems arena. Alternatively, it is recommended that ArvinMeritor select its market entrant strategy based upon insights gained from the rigorous process of generating the innovation's business model. Then, by employing the innovation techniques presented in the thesis, combined with proper emphasis on the identified critical innovation success factors, and a structured project prioritization process (such as Aggregate Project Planning), the firm will generate a powerful stream of short, medium, and long-term innovation projects that offer sustained value capture, thereby strengthening the firm's position in the automotive industry.

## **5.5 Opportunities for Further Research**

The path forward for ArvinMeritor in expanding its competencies into the integrated systems domain is not a trivial one, and opens the door to a number of potential opportunities for further research. The concepts listed below arose while researching and writing this thesis, and are thought to represent key areas for future research:

### ***Testing the Systems-Based Innovation Framework***

This thesis touched on the critical innovation factors affecting profitability at the corporation, and proposed a framework that illustrated the interdependent inputs needed to drive the value creation and value capture "wheels" of a systems-based innovation process. However, as ArvinMeritor's transition is still in its infancy, the pool of systems-based innovations was limited. As the initiative continues, and more of the firm's integrated systems innovations are brought to market, the opportunity for testing the proposed framework to better understand *what matters most* with respect to profitability of systems-based innovations is substantial. Research focusing specifically on the value-creation, or product development side would be particularly interesting.



### *Analyzing ArvinMeritor's Integrated Systems Transformation through the Three Lenses*

Viewing ArvinMeritor through the three organizational behavior *lenses* would produce valuable insights for optimizing the transformation process. The three lenses are the Strategic Design Lens, the Political Lens, and the Cultural Lens, which can be used to address some difficult questions that lie ahead.

The Strategic Design Lens would look at how the flow of tasks and information is designed, how people are currently sorted into roles, how these roles are related, and what organizational structure changes are required for ArvinMeritor to operate efficiently and successfully in the integrated systems arena. Many of the interview comments suggested that the current vertically integrated functional-silos at ArvinMeritor are not conducive to developing integrated systems. *What changes are needed in ArvinMeritor's organizational structure to become the industry's leading systems integrator?*

The Political Lens looks at how power and influence are distributed and wielded, how multiple stakeholders express their different preferences and get involved in (or excluded from) decisions, and how conflicts can be resolved. The key issues in ArvinMeritor's transformation related to this lens might be a fundamental misalignment of incentives between various parties, which creates significant roadblocks for systems integration. An example might be a business unit manager's objectives to tightly manage her profit center resources, which poses real problems when she is asked to devote significant dedicated resources to an integration project driven by a different business unit. Another example is Procurement's management-driven objective to maximize cost savings, resulting in acceptance of the lowest supplier bid, while the integrated systems approach attempts to foster collaboration with key suppliers who provide the greatest overall benefits, not just the cheapest piece price. *How can these incentives be altered or realigned to achieve multiple internal stakeholder buy-in for the integrated systems movement?*

The Cultural Lens looks at how history has shaped the assumptions and meanings of different people within the firm. Many changes have occurred between the legacy companies making up Arvin and Meritor. In the last six years alone, the heritage Meritor personnel have gone through three company name changes. *What issues have been created from this whirlwind merger and acquisition period that occurred at the end of the 20<sup>th</sup> Century and what are the lessons learned that might be applied as ArvinMeritor again changes its strategic corporate direction by becoming a systems integrator?*

***Looking to the Aerospace Industry as a “Lead User” of Integrated Systems Development Processes***

The aerospace industry has long been developing extremely complex systems, driven by supply-chain collaboration through Integrated Product Teams (IPT). IPT membership is made up of multi-functional stakeholders working together with a product-oriented focus. For example, the JSF 135 (Joint Strike Fighter) aircraft, integrates over 15 systems suppliers in nine countries, each with their own supply chains. Teamwork within the framework of Integrated Product Development (IPD) drives the functional and product disciplines into a mutually reinforcing relationship which helps remove barriers to the IPT success. The automotive industry could learn a great deal by approaching the aerospace industry as a “lead user” of integrated system development processes. It would be an interesting exercise to research IPD best-practices and apply the concepts to the development of integrated automotive systems.

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# APPENDIX A

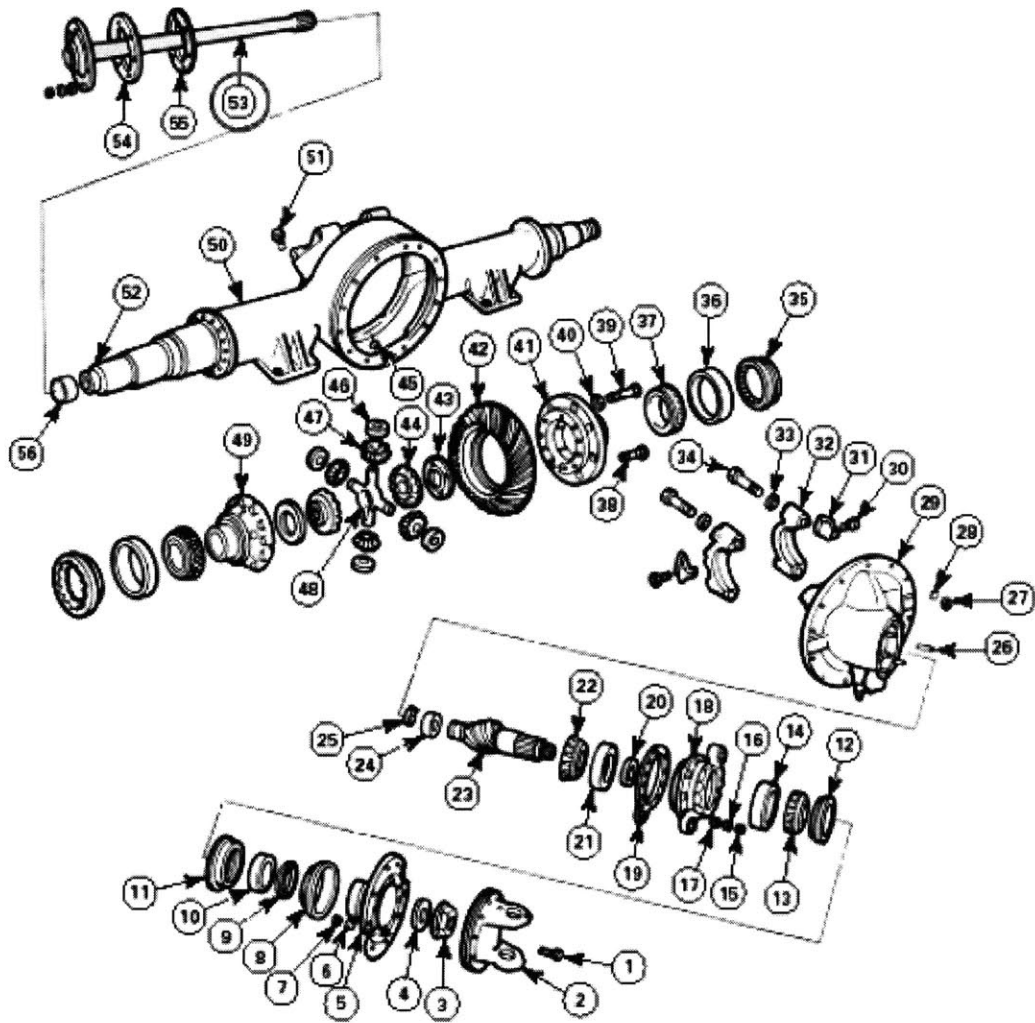
## Case Q1-1: Axle Shaft Process Innovation

### *Background*

Since 1909, when the company formed as Timken Detroit Axle Co., ArvinMeritor has been leading the heavy-duty axle market with reliable, long-life axles and advanced gearing technology. ArvinMeritor's more than 90 years of axle-producing experience has led the company to become the world's largest independent manufacturer of heavy-duty truck axles for a vast range of vehicle applications, including:

- ✦ Linehaul and city delivery
- ✦ Bus and transit coach
- ✦ Trailer
- ✦ Construction and refuse
- ✦ Logging and mining
- ✦ Off-highway and specialty vehicles

Figure A1 shows an exploded view of an axle assembly, with the axle shaft highlighted. The primary function of the axle shaft is to transmit drive torque to the wheel end, to which it is attached. Over the years, a number of design innovations were introduced around the axle shaft, but very little change was made to the design or processing of the shaft itself, which was made from a high hardenability alloy steel, and traditionally quench & tempered to achieve its strength and toughness. In the late 1980's, however, some competitors to ArvinMeritor (then Rockwell Automotive) began selectively induction hardening their shafts, which was found to not only improve the axle shaft performance, but also significantly increase process efficiency. Below is a brief comparison of the two processes.



Item	Description	Item	Description	Item	Description
1	Bolt	20	Spacer*	39	Differential Case Capscrew
2	Propeller Shaft Yoke Flange	21	Inner Bearing Cup	40	Washer
3	Pinion Nut	22	Inner Bearing Cone	41	Differential Left-Half Case
4	Washer	23	Drive Pinion	42	Drive Gear
5	Differential Companion Flange	24	Rear Bearing	43	Side Gear Thrust Washer
6	Washer	25	Lock Ring	44	Side Gear
7	Flange Nut	26	Spider Stud	45	Magnetic Drain Plug
8	Dust Wiper	27	Nut	46	Pinion Thrust Washer
9	Oil Seal	28	Washer	47	Differential Side Pinion
10	Oil Seal Wiper	29	Differential Carrier	48	Spider
11	Oil Deflector	30	Lock Bolt	49	Differential Right-Half Case
12	Oil Seal Retainer	31	Adjusting Ring Lock	50	Axle Housing
13	Outer Bearing Cone	32	Bearing Cap	51	Breather
14	Outer Bearing Cup	33	Washer	52	Load Tube
15	Nut	34	Differential Bearing Capscrew	53	Axle Shaft
16	Washer	35	Adjusting Ring	54	Gasket
17	Dowel	36	Differential Bearing Cup	55	Grease Seal, Optional
18	Pinion Cage, Spider	37	Differential Bearing Cone	56	Grease Seal Sleeve, Optional
19	Shim*	38	Drive Gear Capscrew		

Figure A1: Exploded drawing of axle assembly

### ***Quench & Tempering vs. Selective Induction Hardening***

After machining, steel parts are frequently heat-treated to establish required mechanical properties such as yield strength, hardness, wear resistance, etc. Quench & Tempering is one method of strengthening structural components, whereby parts are heated up to their hardening temperature in a furnace, quenched in some medium such as water, oil, gas, etc., and subsequently tempered to impart toughness. This type of heat treatment is relatively inexpensive, and is an effective method for producing generally uniform properties throughout the part. However, the rapid release of residual stresses associated with quenching a part from above 1400°F down to roughly 200°F can cause distortion in certain designs, including shafts. Rockwell corrected for distortion with a subsequent straightening operation; however this operation was known to have a negative impact on fatigue life. Moreover, the two ends of the shaft (flanged and splined ends) posed formidable quenching challenges, requiring Rockwell to blow forced air on both ends prior to quenching to avoid cracking caused by thermal shock. Yet, another caveat to quench & tempering was that the uniform properties gained by the process may not necessarily provide optimum performance in service if different properties are required in different locations. Selective induction hardening addresses the above distortion and uniformity issues (see Figure A2).

The basic principle behind induction hardening is that the magnetic field produced by an alternating current flowing through a coil generates a current in the adjacent steel part. As the magnetic field expands and collapses, the current in the part changes direction. Internal electrical resistance causes the steel to heat into the austenitic range as the coil *scans* the length of the part, followed by immediate and continuous quenching as the coil moves. With this method, components can be heat treated in seconds, as opposed to hours for quench & tempering, and specific areas (induction patterns) can be selectively hardened by stopping and restarting the coil current during the process. Each selective induction pattern results in a hardened case at the surface of the part, which is ideal for

introducing strength and wear resistance in specified areas without the level of distortion that often comes with rapidly quenching the entire part.

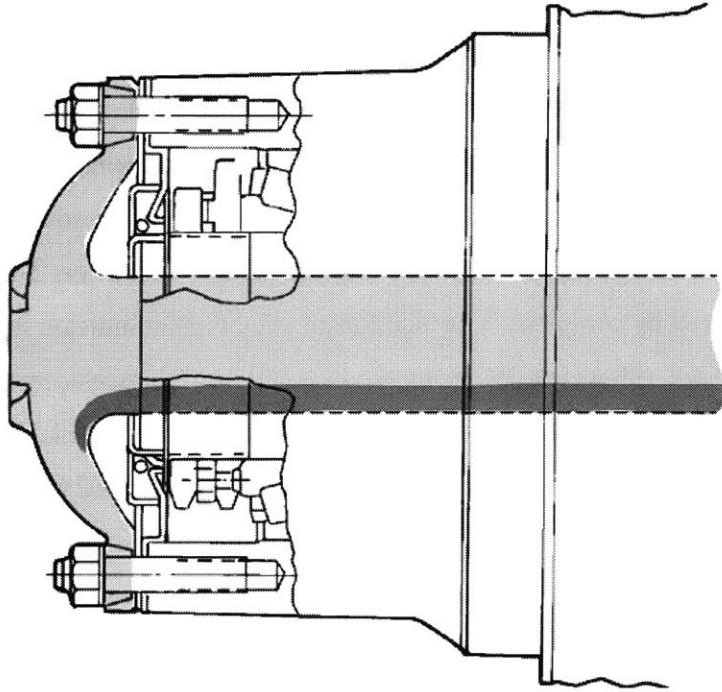


Figure A2: Axle shaft shown in assembled position, attached to wheel end. Quench & tempering is represented by the red shading, which hardens the entire shaft. The blue shading represents the effects of selective induction hardening, which creates a hardened pattern only where high compressive stresses and wear resistance are needed.

### ***Second-mover Innovation leading to a Dominant Design***

As commercial vehicle end-user performance demands continued to increase, it became evident that induction hardened axle shafts were better suited than quench & tempering for meeting customers' changing needs. The increase in desirable surface compressive residual stresses gained by induction hardening was effective in handling higher service loads. In fact, Rockwell's quench & tempered shafts began experiencing increased warranty returns at the same time its competitors' induction hardened shafts were

demonstrating significant increases in axle life. Rockwell's axle business was beginning to lose market share.

In 1990, Rockwell began studying competitors' processing methods in detail as a first transitional step toward induction hardened axle shafts. Out of this benchmarking effort came a series of innovations that leapfrogged Rockwell to the forefront of axle shaft processing, and established the dominant design that defined what is today the industry standard for induction hardened axle shafts. In experimenting with induction frequencies, Rockwell discovered that a 1 kHz frequency, which was 3 times lower than the frequency used by competitors, resulted in an even further increase in surface residual compressive stress. However, the general consensus among producers at that time was that 1 kHz simply produced too much heat for the shaft to handle, and that this frequency was untouchable for axle shaft processing. Rockwell looked at this issue differently, figuring that if there was a way to capture the benefits of the frequency's intense heat to improve process throughput, while not over-heating the part, significant competitive advantage could be gained.

The focus was placed on optimizing equipment and process parameters. A significantly increased scan rate, combined with a new innovation in quench ring design and more powerful quench pumps, was successful in quickly removing the heat from the shaft. Additional equipment innovation was needed however, as the intense heat produced by the 1 kHz frequency was severely reducing the life of the induction coil. After a few design iterations this issue was resolved using a completely redesigned induction coil that met expected life requirements.

After nearly three years of equipment and process innovations (1990-1993), production of 1 kHz induction hardened axle shafts began, and the results were astonishing. The increased scan rate and innovative quenching system needed to avoid overheating the shafts resulted in a nearly 70% increase in throughput. Furthermore, the effective depth



of heating with the low frequency yielded additional (25 ksi) compressive residual stresses along the shaft surface, providing Rockwell with a valuable competitive edge in axle shaft performance.

Rockwell's new process emerged as the dominant design, setting the standard for induction hardened axle shafts. Within 4 years, all axle shaft producers were induction hardening with a 1 kHz frequency.

### *Reaping the Rewards of Innovation*

Rockwell eventually realized a \$3 million annual cost savings from their innovations in axle shaft processing, while dramatically increasing market share. However, the innovation alone did not yield these impressive results. Rather, it was a combination of value creation (i.e. the process innovations) and the ability of Rockwell to capture a portion of that value through its well thought-out business model. Shortly after production began, Rockwell began developing a Canadian supplier, Traxel, to heat treat the shafts. Much of Rockwell's equipment used to process the shafts was very old, and therefore scrapped, but the useful equipment was sold to Traxel. In addition, Traxel invested in new equipment, which enhanced process control and product quality. Finally, a significant portion of the savings was attributed to the attractive Canadian exchange rate and the move to Traxel's non-union (vs. Rockwell's union) manufacturing facility.

## **Case Q1-2: Value Chain Innovation: Customer Value Centers (CVC's)**

### ***Background***

As is stated throughout the paper, creating value through new product innovations and technologies makes up only half of the profitability pie – capturing value from new products is just as critical. Included in the value capture equation is the firm's strategy for delivering the end product to the OEM. Following the lead of the OEM supplier park model, ArvinMeritor has taken the initiative to innovate its logistics strategies, a move that has positioned the firm well for its transition to integrated systems. This case will look more closely at the firm's supply chain concept it calls the Customer Value Center, or CVC, and the benefits that this strategy offers to both OEM and the supply chain. An example of how the CVC contributes to the value creation of an integrated systems business model is also provided.

### ***The CVC Concept***

With just-in-time delivery and lean manufacturing gaining significant momentum in the late 1980's and early 1990's, location shifts to accommodate these principles became the next logical step in the evolution of the automotive supply chain. The concept of the supplier park was introduced to gain further manufacturing efficiencies and cost reductions by clustering a number of key suppliers together in close proximity to the OEM manufacturing plant. ArvinMeritor embraced the supplier park concept, and proceeded to enhance its own supply chain strategies by creating Customer Value Centers. The centers were designed to do more than merely offer OEM's reduced delivery times and route distances; by using CVC's as final assembly and validation facilities for integrated systems and modules, a host of additional efficiencies and cost savings could be realized by both the OEM and the supplier. In less than a decade, more than 20 ArvinMeritor CVC's have been launched in one of three variants: (1) a stand-alone CVC in close proximity to the OEM, (2) a plant-within-a-plant, where the CVC is operated out of an existing ArvinMeritor product facility, and (3) a CVC residing within the OEM assembly plant.

The stand-alone version seems to be the prevailing model. One example is ArvinMeritor's CVC in Sao Paulo, Brazil, which operates less than one-third of a mile from the Volkswagen Polo assembly line. In this 14,500 square foot CVC, employees weld and test muffler modules, using components from a nearby ArvinMeritor Light Vehicle Systems facility in Cambui, Brazil. The exhaust modules (integrated down-pipe and muffler assemblies) are fitted into special racks in the sequence of the line and delivered to VW every 30 minutes.

The experience ArvinMeritor has gained with its CVC concept has begun to enhance its value proposition, making potential new product offerings more economically attractive to OEM's. In fact, ArvinMeritor has determined the OEM contract size that makes the construction of a new CVC financially viable, and has a standing offer to all OEM's to build a CVC in close proximity to their final assembly plant for all contracts exceeding this dollar amount. The CVC model becomes attractive, however, only with a solid understanding of the customer needs and the benefits gained by both the OEM and supplier when viewed through a holistic lens. These benefits are discussed next.

### ***OEM Benefits***

For OEM's, the value of CVC's are inline with those gained by the supplier park concept. Close proximity of key suppliers all near the OEM creates sub-assembly synergies as well as savings on overhead and transportation. With subassembly, suppliers simplify the build process at the vehicle assembly facility, resulting in a number of benefits including reduced space requirements, reduced labor costs, decreased forklift traffic, reduced inventory, reduced scrap and improved quality. What the OEM sees is a completed, fully tested, fully warranted modular component, such as a complete door, delivered to the right location, for the right vehicle, at the right time.

Dr. David Cole, director of the Center for Automotive Research (CAR, Ann Arbor, MI), contends that subassembly helps automakers substantially reduce manufacturing costs.

When a supplier manufactures components in a facility near the final assembly plant, it eliminates shipping costs and expensive containers. Additionally, the cost of carrying inventory is nearly eliminated, and on-time delivery risk is greatly reduced. The close proximity also facilitates immediate feedback of quality issues that reduce scrap and improve throughput, which are also key principles of lean manufacturing. Above all, subassembly helps reduce time-to-market.

According to Roman Krygier, Ford group vice president of manufacturing and quality, ~~the supplier plant is responsible for the~~ ~~flexibility~~ ~~and~~ ~~allow~~ ~~for~~ ~~quicker~~ ~~response~~ ~~to~~ ~~customer~~ ~~preferences~~. Krygier explains, "Flexible manufacturing is critical to allow automakers to respond quickly to changes in customer demand and adjust products according to market trends." Furthermore, Krygier contends that flexibility enables OEM's to create additional manufacturing efficiencies, "We are bringing in new ~~production concepts and tooling that greatly enhance the~~ ~~and~~ ~~speed~~ ~~and~~ ~~quality~~ efforts. For example, an electrified monorail system and flexible tooling will allow rapid changeovers—even if we switch from a small car to an SUV."<sup>26</sup> Another example is a conceptual model that Ford has created, called the "pay on production" plan that would shift the cost of tooling to suppliers. This concept is designed to free up the automaker's finances by requiring suppliers to take on more upfront costs. Under this type of system, which was developed at the Ford plant in Cologne, suppliers would pay for and own tooling and other production equipment that the automaker normally would have purchased. The automaker repays the cost through production, with payments credited as each car rolls off the assembly line.

### ***Supply Chain Benefits***

Customer Value Centers benefit ArvinMeritor and its supply chain in numerous ways. In addition to many of the same logistical benefits also enjoyed by the OEM, such as

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<sup>26</sup> Weber, Austin. "Auto Suppliers Move Closer to Assembly Lines," *Assembly Magazine*, May 2004.

reduced shipping costs and improved response time, one of the most important benefits of the CVC is that it eliminates the ambiguity and uncertainty of production forecasting. The higher level of communication between the CVC and the OEM, coupled with the significantly improved response time, allows the CVC to more accurately plan production. This quicker response to a more accurate demand translates to a reduction in working capital through the more effective utilization of resources.

In some cases, a significant cost reduction can occur by using the CVC for producing only the most value added portion of the system or module, and outsourcing the rest. For example, ArvinMeritor is considering the use of a CVC for production of its next-generation modular valve shock absorber. Currently, the company manufactures the entire shock absorber assembly, including cutting and machining the inner and outer cylinder tubing, machining and chrome plating the piston rod, and manufacturing the valve components. For the modular valve shock, the intent is to focus development resources on only the most complex portion of the shock, the valve design, which can provide ArvinMeritor with a competitive edge in the market. All other components and processes would be outsourced, and would be shipped to the CVC for final assembly. This strategy would significantly reduce costs by eliminating numerous manufacturing and processing steps of commodity subcomponents, as well as the overhead associated with equipment and personnel.

In a supplier park setting, opportunities arise for cross-tier supplier relationships. For example, an electronic systems supplier might ship main-body wire harnesses directly into the OEM plant. At the same time, it might also deliver harnesses to other tier-one suppliers for use in their subassemblies. Tom Lewis, VP of Logistics for ArvinMeritor, stated that an unintended, but powerful benefit resulting from the supplier park CVC was the affect it had on employees. He explained that the CVC employees, being so close to the OEM, gained a better understanding of the 'big picture' and developed a strong sense of ownership in their contributions to the OEM final assembly process. In fact, the

employees became so in-tune with their customer's needs, that their efforts were more focused on what was needed to keep the OEM assembly line running, rather than their own. When problems arose at the OEM plant, whether it was related to ArvinMeritor's product or not, a troubleshooting team was assembled to assist the OEM in resolving the issue. These efforts help build partnership relations with the OEM, as opposed to the often adversarial customer-supplier relationships commonplace between US OEM's and their suppliers, and bring all of the stakeholders one step closer to forming a collaborative supply chain enterprise.

#### ***Well Suited for Integrated Systems & Modules***

The following example illustrates the important role that CVC's played in enhancing the value proposition of an integrated brake and front steer axle module (Figure A3) recently proposed to a commercial vehicle OEM. OEM's are shifting their choice of braking technologies from the standard drum brake design to air disc brakes, reluctantly however, since air disc brakes are significantly more expensive. This shift was prompted by a Federal Motor Vehicle Safety Standards (FMVSS) proposal for a 30% reduction in stopping distances in commercial vehicles by 2007, as well as a strong endorsement of air disc brakes by the National Highway Traffic Safety Administration (NHTSA). The integrated brake/axle module was ArvinMeritor's response to OEM pressure placed on suppliers to reduce the cost of air disc braking systems.

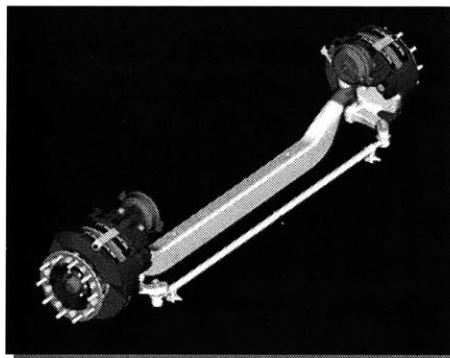


Figure A3: Computer-rendered view of air-disc brake & front steer axle modular assembly

In this proposal the air-disc brake remains more expensive than the conventional drum brake, however the value proposition becomes attractive by bundling this product with ArvinMeritor's new lightweight front steer axle assembly, and introducing CVC's to perform the integrated module subassembly. In doing so, the end result is a better performing product with reduced overall cost and weight in comparison with the OEM's current design. The enhanced performance comes from the superior stopping power of the air-disc brake, which is increased even further by the reduction in vehicle weight with ArvinMeritor's new lightweight tubular front axle design. A larger drum brake design offered by competitors will also meet the proposed new stopping distance requirements, however at significant cost and weight penalties. The cost reduction stems from the combination of substantial savings offered by the tubular front axle design, and the cost-reducing freight, assembly, and labor efficiencies brought on by the use of CVC's, which are discussed further below.

The reduction in freight costs is illustrated in Figures A4 and A5. Figure A4 shows the current supply chain routes to the OEM final assembly plants (blue dots). This scenario includes shipments from five tier-one suppliers with a total of 15 shipping lanes, one of which has a distance greater than 2300 miles. The proposed CVC routing, shown in Figure A5, is a much simplified supply chain. Four regional CVC's, three of which would be within 60 miles of the OEM, shorten freight time, and significantly reduce both working capital and inventory. Shipping lanes are reduced from 15 down to 5, and a cost study resulted in an estimated freight savings of greater than 70 percent (cost figures omitted for proprietary reasons).

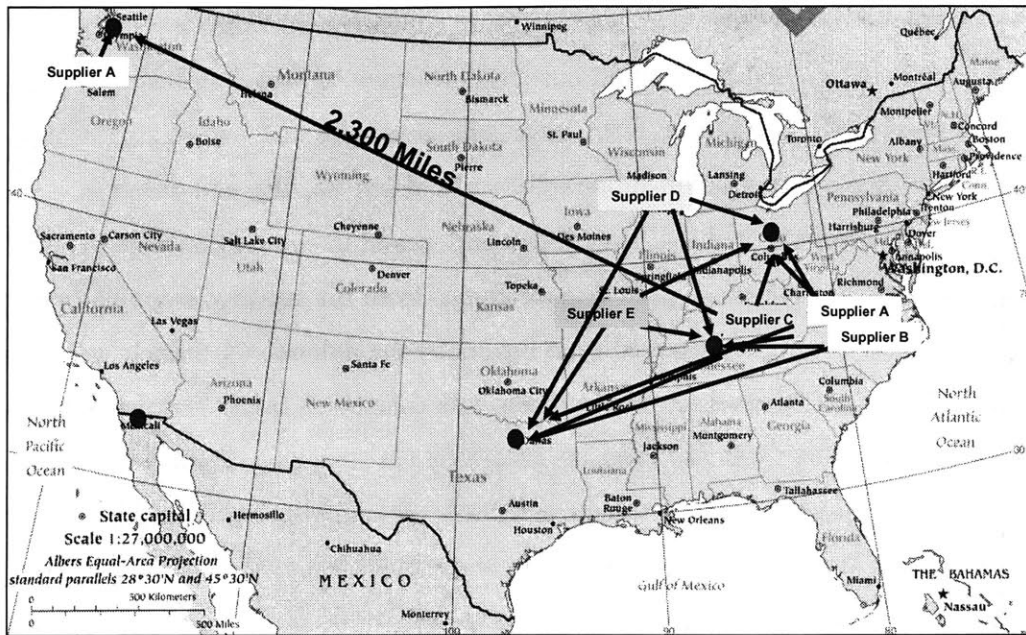


Figure A4: Current supply chain routes



Figure A5: Proposed supply chain routes using the CVC model



Assembly and labor expenses are reduced by utilizing the CVC's to perform all of the OEM non-core subassembly processes. These include:

- ◆ Installation of Brakes to Axle
- ◆ Wheel-end installation and bearing adjustment
- ◆ Air Chambers to Brake assembly
- ◆ Integrates Slack Adjuster into the Brake assembly

In addition, the OEM part numbers per assembly are reduced from 8 to 1, and people-minutes per assembly are reduced from 45 minutes to just 15 minutes. Overall, the use of CVC's reduces total assembly and labor expenses by more than 60% (cost figures omitted for proprietary reasons).

In summary, Figures A7 and A8 illustrate the overall "system" value-proposition offered by the integrated air-disc brake/front steer axle module. Using a three-axis value chart (cost, weight, and performance), the integrated approach is the most attractive. Figure A6 shows the value-proposition for the conventional brake drum (green triangle) and larger brake drum (blue triangle), both equipped with a standard forged I-beam front axle. The conventional brake drum design is most cost effective and is therefore shown to be nearly 100 percent on the cost value axis, but its value drops progressively in the weight and performance categories, especially since it will not meet the tightened stopping distance requirements expected in 2007. The larger brake drum performs considerably better in terms of stopping distance, however the trade-offs are increased cost and weight.

Figure A7 illustrates the overall value improvement of the integrated air-disc brake/tubular steer axle module offered by ArvinMeritor. The weight is substantially decreased with the ArvinMeritor patented tubular axle beam design, which is approximately 60 pounds (~ 30%) lighter than a conventional forged I-beam axle. The weight savings acts to further enhance the superior stopping power of the air-disc brakes,

and thus maximizes performance. Finally, by taking a systems-view approach that fully considers design, manufacturing, assembly, and logistics, the improved weight and performance can be achieved at a cost that is slightly lower than the OEM's current inferior product.

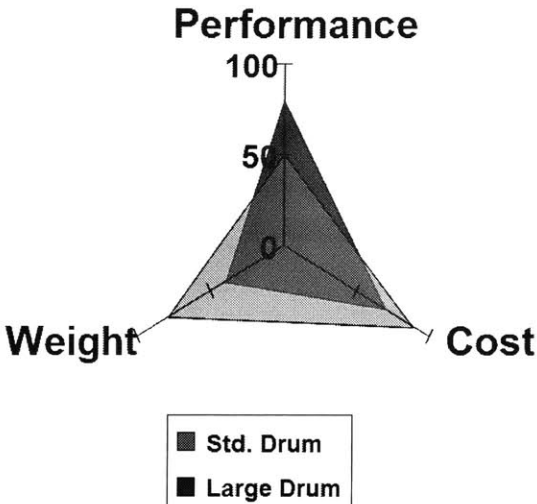


Figure A6: Value chart of Standard & Large Drum Brakes with forged I-beam axle

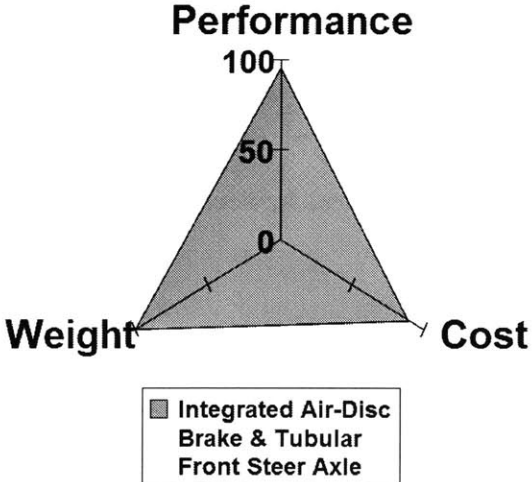


Figure A7: Optimized value with Integrated Air-Disc Brake/Tubular Axle Module

Note: Figures A4-A8 extracted from ArvinMeritor business model presentation by Gary Ganaway

## **Case Q2-1: RHP-11 Highway Parallelogram Air Suspension System**

### ***Background***

Commercial vehicle suspensions have made significant strides in design and process innovation for the tractor/trailer and bus & coach markets since the late 1980's, at which time the majority of new trailers were still equipped with steel spring and walking beam suspensions. Only roughly 10% of new trailers offered air suspensions, not because drivers, owner operators, and fleets didn't want air suspensions, but because the components were much higher in cost and weight than the mechanical suspensions.<sup>27</sup> While air suspensions offered a number of advantages, including improved ride quality, stability, and durability, the added cost was simply not justified.

Over the past 15 years, however, suspension suppliers have made advancements in both trailer air suspension design and production methods, which have resulted in a reduction in the premium paid for air suspensions by more than 50% on some trailers, and weight reduction of about 20%. These innovations made air suspensions much more competitive with mechanical suspensions, and resulted in broadening customer needs. Instead of the almost exclusive focus on price and weight, customers began demanding additional attributes such as superior ride and handling, safe transport of fragile cargo, and even driver comfort. Because trailer air suspensions addressed these demands, the percentage of new trailers with air suspensions rose dramatically throughout the 1990's, and today are up to more than 60%.<sup>28</sup>

### ***The RHP***

In 1996, after performing a detailed engineering and customer analysis, from which many of the above points were drawn, and conducting cost/benefit, market segment, target margin analyses, ArvinMeritor (then Rockwell Automotive) made the decision to design and produce an integrated trailer axle/brake/air-suspension system. Rockwell was

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<sup>27</sup> Bob Zirlin, Director of Worldwide Marketing, Suspension Systems and Trailer Products, ArvinMeritor, Inc.

<sup>28</sup> Bob Zirlin

essentially a second-mover with this initiative, as rival competitor Hendrickson had been the first to launch such an integrated product, called INTRAAX. Using the benchmarking information acquired from the INTRAAX design, and data from the thorough customer and industry analyses, Rockwell proposed a clean-sheet approach that improved upon Hendrickson's design while addressing identified emerging customer needs. The seed from which this integrated suspension innovation, named the Rockwell Highway Parallelogram (RHP), grew was from the creative concepts of an entrepreneur name Ervin vandenBerg, founder of Innovative Suspensions, a small company that Rockwell partnered with, and eventually acquired, during development of the RHP. The RHP value proposition was to provide an integrated brake/axle/suspension system that offered a smoother ride for both driver and cargo, very low maintenance, and the elimination of "dock walk", all in a compact design that was both smaller and lighter than what was currently offered by the competition. Dock walk refers to the nagging problem of trailer movement away from the dock due to repetitive forklift impact, a phenomenon that intensified with air suspension designs, and that was not addressed by Hendrickson's INTRAAX. The intention of the RHP design was to create vertical, rather than horizontal, frame movement during forklift loading and unloading, thus eliminating dock walk without using heavy add-on devices, the only available solution at the time. Table A1 lists the main design features and benefits of the RHP.

A combination of suppliers, partners, and even a consulting firm assisted Rockwell engineers with the RHP design. As the product design phase was transitioning into the process development phase, a surprising turn came, as one member of the lean, three-man trailer sales account staff called in an order from a major OEM for 5500 RHP's, unanticipated at this very early stage of the development process. While this was great news for the program, the order size was orders of magnitude greater than Rockwell's current production capability, which was five hand-built units/day at Innovative Suspension's headquarters in Canal Fulton, OH. Senior management quickly stepped up and provided necessary resources to aggressively ramp up production, including moving

the manufacturing operations to a much larger and more equipped facility in Frankfort, KY.

Features	Benefits
Efficient sliding tandem that is centered on a single, unified frame bracket.	Results in a compact design that is at least 26% shorter and weights up to 255 pounds less than conventional trailing arm suspensions.
Design features upper and lower control arms, which create vertical, rather than horizontal, frame movement during forklift loading and unloading.	Eliminates dock walk without any heavy add-on devices.
Eliminates suspension-induced backslap, creating a smoother ride for driver and cargo.	Keeps landing gear stable, and doesn't dig into the asphalt.
Parallel design allows air springs to be located directly over the axle, rather than behind.	Provides a great ride and perfect equalization.
No roll torque on the axles, unlike trailing arm suspensions.	Reduces stress on the vehicle.
Design uses half as many shock absorbers as other trailer suspension systems.	Reduces weight and maintenance costs.

**Table A1: RHP Features and Benefits**

***Innovation Leading To Product Success***

The innovative features listed in the table above resulted in a differentiated trailer suspension system that provided unparalleled functionality and driver satisfaction in the markets it served. The success of the design earned Rockwell, which became Meritor Automotive in 1997, the coveted PACE Award (Premier Automotive supplier's Contribution to Excellence) in 1999, as shown in Figure A8. In addition to the product

innovations that led to the PACE Award, a number of quality-enhancing process innovations were also created. Perhaps most notable among these was the patented *Laser-line* alignment process, which utilized laser technology for precision alignment of the axles to the slider box, thus optimizing the distribution of loads across the trailer axles. Another innovation, which significantly improved process repeatability, was the implementation of computer torque-controlled nut-runners.

Jim Grant, Chief Engineer of ArvinMeritor's CVS Trailer Division, attributes the success of the RHP program to three main factors:

1. Understanding the needs of the customer and the market
2. The competence of the Rockwell Trailer and Suspension engineering staff
3. Effort put forth by the trailer division sales staff to secure early orders for the product.

Understanding the customer and the market acted to not only provide the engineers with the information needed to create value with their integrated design, but also allowed Rockwell to capture value from the innovation by successfully addressing the customers' evolving needs, leveraging strong customer relationships, and generating competitive advantages through differentiated product and process attributes. Instrumental in this process was the technical capability of the engineering team, who took an "enterprise approach" to the systems design by integrating suppliers and other outside technical experts into the design process. The competence of the trailer and suspension engineering staff was essential in taking the creative, but somewhat unrealistic, concept from Innovative Suspensions, and transforming it into a realistic integrated system, in terms of engineering, manufacturing, and packaging. Finally, had it not been for the diligent work of the sales team to promote the RHP and secure the initial order, the needed development resources may not have been allocated.



Figure A8: 1999 PACE Award recognizing innovative achievements of the RHP system.

## Case Q2-2: Low-Floor Axle

### *Background*

As the next generation of transit coach and bus designs evolves, it has become apparent that one design trait in particular has emerged: low-floor designs.

For many years, elderly and handicapped people, as well as the average bus rider, have been inconvenienced by the conventional high-floor buses, which include steps near the entrance. Over the past decade, bus and coach manufacturers, as well as component manufacturers, have recognized this issue and have responded to the trend with newly designed products intended to make conventional high-floor buses a thing of the past (see Figure A9).

Today, virtually all bus OEM's have launched or will offer low-floor bus designs. The movement has been strongest in Europe, which boasts the largest bus market in the world with more than 15,000 coaches and approximately 10,000 city buses.



Figure A9: Improved accessibility with low-floor axles



### *New Strategy for a New Market*

In 1993, when the trend of low-floor axles first emerged in Europe, ArvinMeritor considered the new technology as both a threat and an opportunity. It was feared that by not entering the low-floor market in Europe, ArvinMeritor's North American Bus & Coach business could face disruption if the trend carried over to the U.S., at which time sufficient competitor momentum would be built making it difficult for ArvinMeritor to defend its N.A. market position. However, entering the market early presented an opportunity to capture a piece of the European pie, and would better position ArvinMeritor to develop the technology in the US, not only in the bus & coach market segments, but also for specialty delivery trucks which might benefit from improved vehicle accessibility.

The decision was made to enter the low-floor axle market, and ArvinMeritor next needed to develop its strategy for doing so. Three alternatives were considered: (1) design and engineer the product in-house, (2) acquire a firm with low-floor axle expertise, or (3) partner with a firm in a joint development effort. It was determined that the quickest, easiest, and least expensive means of penetrating the market was with option 3, and in 1994 ArvinMeritor entered into a partnership agreement with the Italian firm, Graziano Transmissioni. Graziano had begun making strides in the European low-floor market, with concept designs and tooling investments already made. It was agreed that ArvinMeritor's role was to assist in optimizing the low-floor axle configuration and lead the sales & marketing efforts, while Graziano focused on manufacturing. Two important attributes of the agreement, which were heavily in Graziano's favor, were that the Italian firm would control all European distribution, and would also retain ownership of all intellectual property, enabling them to charge a licensing fee to ArvinMeritor for sales/distribution of low-floor products to all non-European parts of the world.

### *The Technology*

Conventional transit bus and shuttle designs required a three-step entry into the vehicle. To fit the necessary components in the undercarriage – such as axles, steering gear, fuel and air tanks – the floor height must be greater than 30 inches. New low-floor bus designs call for only a 14 to 15-inch height to the bus floor over the front axle with a slight rise or small steps toward the rear axle. This meant that axle components had to be redesigned to fit these new requirements. ArvinMeritor redesigned its standard drive and steer axles and brake products to configure to the new low-floor buses, making a complete new platform of drive and steer axles tailored to this product family.

In these low-floor buses, the floor height at the entrance door is roughly 15 inches high compared to 35 inches for the high-floor buses. The only way to accommodate a floor height this low is to design an axle with a large drop in the center. ArvinMeritor responded with a new axle design, the FH-946 (see Figure A10). Between the axle beam pads, the axle has a drop which was previously the deepest drop in the company's steer axle line-up.

There are two types of basic low-floor designs. One consists of a flat floor throughout the bus, while the other consists of a full-low floor in the front two-thirds occupying the space between the front and center door. The rear one-third has a higher deck which is reached with two steps (see Figure A12). In effect, there are two platform heights inside the bus. Each of these variations requires a different drive axle. The full low-floor design requires a drive axle with a drop from the axle's wheel-end to the carrier, called an *inverted portal axle (IPA) design* (see Figure A11).

Figure A10: FH-946 Axle



Figure A11: Inverted Portal Axle (IPA)



The two-platform approach requires a different drive axle design. An important contributor to floor height in the rear platform of this type of a bus design is the size of the axle center bowl. The axle manufacturer must consider the tire radius, add in the axle bowl radius and finally, design in the required height for suspension travel. The total of these three items will set the floor height at around 28 inches in the rear deck of the two-platform design. In order to minimize the impact of the carrier bowl size in this equation, ArvinMeritor developed an axle with planetary reduction in the wheel-end. This permits a smaller ring gear in the center section, which equates to a smaller axle center bowl.

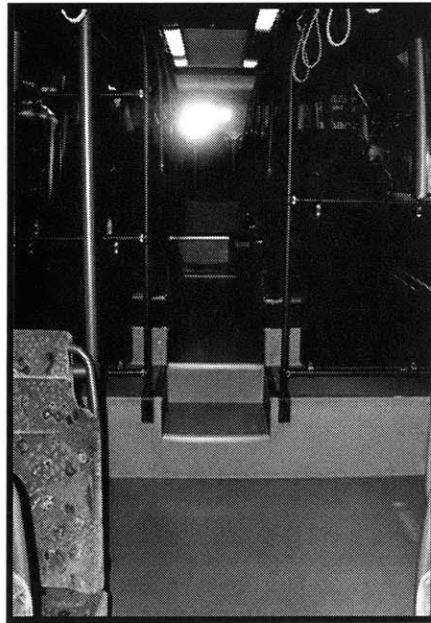


Figure A12: Combination full-low floor and two-step deck

### ***The Benefits***

The benefits of the low-floor bus design were highly visible, and very useful to a number of different stakeholders. The benefits are listed below:

- Quicker speed of boarding passengers, which is especially important during heavy traffic times. This helps bus operators save time, support schedules, and accelerate service.
- Easier handicap access through the use of flip-out ramps instead of standard lifts. In addition to the reduced maintenance required of these ramps, the design meets requirements of the American Disabilities Act.
- Easier passenger boarding. This is especially good for routes with senior citizen centers, schools, hospitals, airports or shopping districts when passengers may be carrying luggage or packages.
- Increased visibility for drivers due to lower windows throughout the bus.
- The modular design of this axle family greatly simplifies service by allowing the center housing, drop gear housings and wheel ends to be assembled and serviced independently.

### ***Profitability***

The low-floor axle business has been profitable for ArvinMeritor, due in large part to the low overhead involved since Graziano was responsible for manufacturing and inventory. In this case ArvinMeritor acted as a second mover, minimizing research and development expenditures, and capitalizing on reduced market uncertainty. The tradeoff, however, is that the first mover, ZF, holds over 80% market share, while ArvinMeritor/Graziano hold just over 15%, and ZF is perceived as the technology leader in the low-floor axle market.

The 10-year agreement between ArvinMeritor and Graziano expires in 2004, leaving ArvinMeritor at a strategic fork in the road. Can the company capture more value by parting ways with Graziano and developing its own product, while differentiating the next generation low-floor axle product from the Graziano-owned intellectual property that ArvinMeritor helped develop? Should the partnership be renewed, allowing Graziano to continue reaping the European benefits and collecting licensing royalties from ArvinMeritor? Should ArvinMeritor purchase the rights to the design and IP from Graziano?

## **Case Q2-3: LFI Composite Roof Module**

### ***Background***

The roof module market is still at a relatively early stage of development, however ArvinMeritor is betting that the growing interest among OEMs for complete integrated roof modules will continue and anticipates the market to increase by more than \$300M over the next four years. ArvinMeritor emerged as the technology leader in the roof module market with the successful launch of the MCC Smart car roof. This breakthrough design incorporated a hard polymeric layered outer shell and an interior headliner with polyurethane composite sandwiched between them for added strength and rigidity. Future modules are slated to be packed with functionality, including sunroofs, sun visors, grab handles, audio speakers, rain sensors, and even solar panels.

The move toward roof modules was established from identification of OEM and end customer needs, which include the following:

- End consumer demand for greater variety within a single vehicle line
- Drive towards product differentiation
- Continued pressure to reduce cost/weight
- Need for greater level of vehicle integration

### ***History***

ArvinMeritor was looking for a way to improve market penetration of its sunroof products in the early 1990's, as air conditioning was becoming more popular among consumers, significantly driving down sunroof sales. In 1993, ArvinMeritor's sunroof division came up with the idea that more sunroofs might be sold if the product was bundled into a complete roof package. A project was then initiated to develop a whole

roof by incorporating both the exterior panel and the interior headliner, and also adding a radical twist: using composites instead of steel *and* eliminating the need for paint.

ArvinMeritor partnered with a number of suppliers on the cutting edge of polymeric materials and processes to develop the paintless film roof module, spending nearly 6 years and \$15M in R&D efforts. However, difficulties in color matching the polymer film to the auto body paint, and in achieving a Class-A finish (finish quality level achieved with paint) hampered the program. The company attempted to hide its inability to overcome these difficulties by instead producing a grained matte surface (see Figure A13). This attracted only one OEM, Daimler-Chrysler, who was developing a low-cost, light weight, compact car designed for use in the narrow streets of Europe. This car, called the MCC Smart Car, avoided the color matching and class-A finish difficulties because the car's plastic body panels, which were all plastic, were meant to be different colors, and the grained roof simply "fit" the look (see Figure A14).

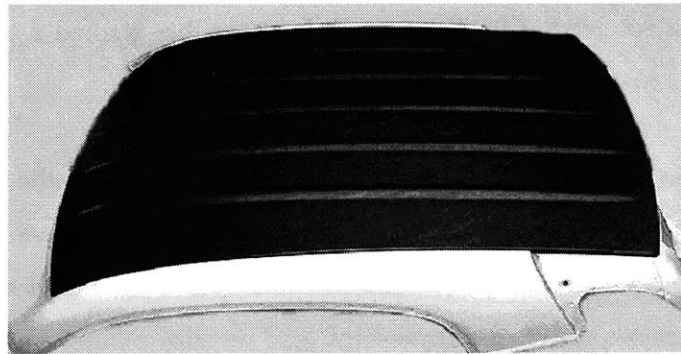


Figure A13: MCC Smart Car matte finish roof module



Figure A14: MCC Smart Car

The Smart car roof module went into production in October 1998 as the first-ever paintless film automotive composite module, selling approximately 14,000 units the first year. The Smart targeted a niche market, however, and although ArvinMeritor earned its reputation as the technology leader in roof modules, the innovation was not profitable. Therefore, in 1999 the group focused its efforts on broadening OEM interest by replacing the outer “paintless film” layer of the composite roof with a thin aluminum foil that was painted to match OEM platform colors and offered a Class-A finish. This design still eliminated the OEM’s need to paint the roof, and remained a light-weight alternative to the steel roof. Prototypes were made and presented to OEM’s, however little interest was received. OEM’s made it clear that they wanted a composite paintless film exterior, not prepainted metal.

A renewed focus on customer needs brought the team back to the issue of achieving matching colors and finish requirements. Greater efforts to interact with the customer paid off with OEM-funded research projects to improve the paintless film technology. After creating new supply-chain partnerships (and severing others) ArvinMeritor was able to produce a high quality, Class-A finish for black roof modules in 2000 (see Figure A15). In fact, it could achieve a Class-A finish for any desirable color, however there were still issues with exact OEM color matching.



The black module is currently in production, and is profitable. Research is ongoing to achieve consistent color-matched finishes with OEM paints, with metallic paint finishes presenting formidable challenges. Progress is being made however, as ArvinMeritor is conducting six OEM-funded research projects for paintless film and the next generation, function-packed, roof systems.

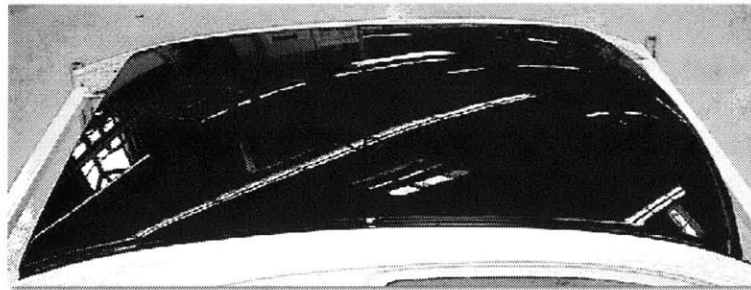


Figure A15: Class-A composite roof module exterior.

### ***Roof Module Technology and its Advantages***

The sandwich structure of the composite roof module is shown in Figure A16. The Class-A surface is provided by a tough multi-layer polycarbonate (PC) film which carries the required color. This is vacuum formed into the mold as the first of four stages that produce the basic shell.

Next, the main structural component is added to the mold. The company's core technology for roof modules is reaction injection molding (RIM) polyurethane (PU) with long fiber injection (LFI), for which ArvinMeritor has developed a proprietary technology. Continuous glass fibers feed off a spool and are cut to length just at the point where the two components of the PU thermoset are mixed. This allows fibers of multiple lengths to be incorporated into PU paste as it is sprayed into the mold. After polymerization in the mold, the part is ready for machining as necessary to incorporate

sunroof openings, lighting or audio systems, grab handles, etc. Finally, the headliner is adhered to the PU composite, completing the module.

The LFI technology is the key to the design. Use of this structural composite results in a weight savings of up to 40% compared to that of a standard steel roof, can be easily customized to achieve different thicknesses exactly where needed, and perhaps most importantly, improves safety. ArvinMeritor has conducted side impact tests which show how the bonded structural composite roof module can significantly reduce B-pillar intrusion depth, even without the traditional three-bow body-in-white (BIW) roof structure.<sup>29</sup>

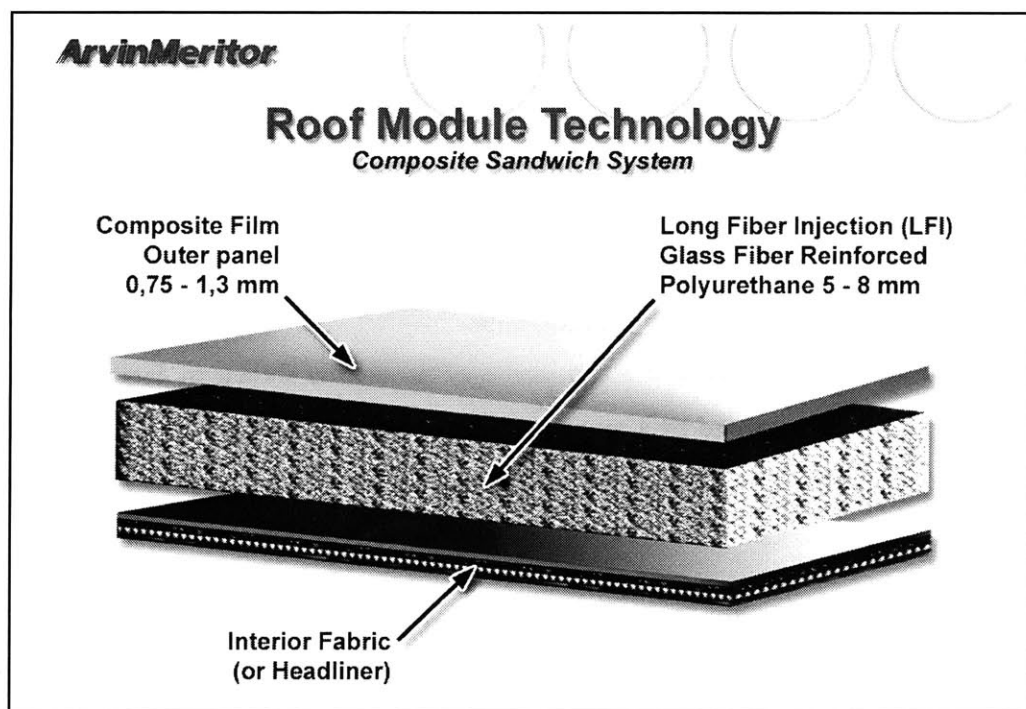


Figure A16: Composite roof module cross-section

<sup>29</sup> "On top of the game", European Automotive Design, April 2003, p. 22-23.

A number of benefits are offered to the OEM with ArvinMeritor's roof module, with perhaps the most important being the much improved vehicle accessibility during assembly. This was achieved by ArvinMeritor's completely new technique for roof assembly to the BIW on the OEM assembly line. The module is assembled to the frame in a drop-in fashion, and because all of the functions are integrated into one modular piece, the BIW can be standardized. This allows OEM's assembly flexibility by enabling them to install various interior systems (seats, instrument panels, interior trim, etc.) through the roof opening, and then dropping the roof in after. Other advantages include reduction of OEM manpower, training, inventory, and logistical costs, as well as simplified disassembly and serviceability.

For consumers, the composite roof module offers improved safety, a more dent resistant, scratch resistant exterior, improved fuel efficiency through weight reduction, and allows the customer the ability to remove the roof and replace it with other modular configurations such as sunroofs, t-tops, canvas accordions, etc.

The ArvinMeritor Roof Systems division attributes the success and profitability of the composite roof module to really understanding what their customer needs are, and developing strong collaborative partnerships not only with key suppliers, but also with OEM's. Close and frequent interaction with the OEM does more than help tier-ones understand customer and end users needs, it also enables the tier-one to play a part in *shaping and influencing* those needs, and streamlines R&D by defining a clear technological focus. The Roof Systems division has established a culture of technology leadership, which is an interesting contrast to the over-arching corporate culture that appears to be largely that of a second mover. Moving forward to the development of complex integrated systems, the corporation would be wise to learn from this division's best practices in creativity and enterprise collaboration.

### **Case Q3-1: ZF-Meritor Single Rail Top Cover**

#### ***Background***

An automotive transmission is a complex system of torque generating gears and shafts that changes the ratio of the engine speed and the wheels by connecting the gears in various combinations (Figure A17). For example, first gear connects the engine power to the drive wheels via a pair of reduction gear sets, which gives increased power and reduced wheelspeed when the car is beginning to move. Gears work exactly like levers. A small gear driving a larger one gives an increase in torque, and a decrease in speed, and vice-versa. The transmission interfaces directly with a the vehicle's driver, via the shift lever, as well as with a number of other vehicle subsystems and components, including the clutch, drive-train, and an increasing number of vehicle computer control systems. This case discusses a failed redesign of the transmission's top-cover assembly, which houses the gear selection mechanisms that interfaces with the shift lever operated by the vehicle driver.



Figure A17: Transmission shown integrated with clutch assembly

In 1997, after learning that it's major competitor, Eaton, was in development of a new commercial vehicle transmission, with a redesigned top-cover that eliminated two of the

three shift rails, ZF Meritor decided that it must also develop a single-rail top-cover and incorporate it into their newly designed G-platform transmission. ZF Meritor is a 50/50 joint venture formed between Meritor Automotive (now ArvinMeritor) and ZF Friedrichshafen AG in 1999 to produce medium- and heavy-duty transmissions for heavy vehicle original equipment manufacturers and the aftermarket in North America.

### *Top-Cover Designs*

ZF Meritor's current three-rail top cover design performed adequately however was cumbersome to assemble because the use of a lock wire was needed to retain any bolts that might have accidentally been dropped during installation. This added time to the assembly process and was ergonomically unfriendly. In addition, ZF Meritor's Marketing group reported driver complaints of a somewhat poor "shift feel", describing the three rail design as a bit "notchy". By designing out two of the shift rails, the complexity of the assembly process was significantly reduced, allowing throughput to increase. In addition, overall cost and weight of the transmission were reduced, and with only one rail the driver shift feel was expected to improve. The two designs are shown in Figure A18.

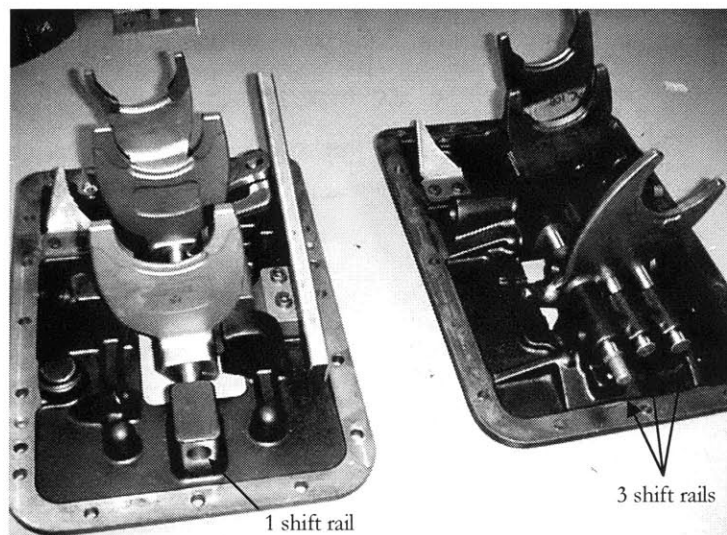


Figure A18: Single-rail and Three-rail top-cover designs

### *A Recipe for Disaster*

A combination of schedule pressure, legacy architecture constraints, and an insufficient understanding of system-level requirements ultimately led to the program's demise. The single-rail top-cover launched in 2000 amid intense schedule pressure. In addition to trying to catch up to Eaton, which was first to market with their single-rail design, the single-rail development team was pushed hard to launch in sequence with another ZF Meritor transmission innovation, a noise-reducing rear auxiliary box. As a result, single-rail development problems regarding the poor correlation between FEA (finite element analysis) and laboratory test results, as well as the unrepeatability of validation tests, were not resolved before launch. In addition, the number and length of field tests were shortened.

Design space limitations resulted in constraints on design flexibility, which then led to additional constraints on manufacturing and processing of the component that turned out to be the single-rail's Achilles heel. Redesigning the top-cover within the legacy G-platform transmission architecture forced the design of three relatively complex shaped shift bars that interfaced with the shift rail in the gear selection process. FEA predicted that the shift bars would see very little stress in the application, but needed to hold tight flatness tolerances and exhibit good wear resistance. Material and process selections for the shift bars were based on these requirements (SAE 8620 alloy steel, ferritic nitrocarburized). The shift bar location in the single-rail assembly is shown in Figure A19.

Less than one year after the single-rail launch, shift bars began to fracture in the field (Figures A15 through A17). Laboratory fracture analysis results concluded that low cycle bending fatigue was the mode of fracture, which left ZF Meritor design engineers scratching their collective heads since there was thought to be no bending stresses on the shift bars. The impact witness marks on the bars suggested excessive shifting force, and ZF Meritor began denying warranty claims based on suspected driver abuse.

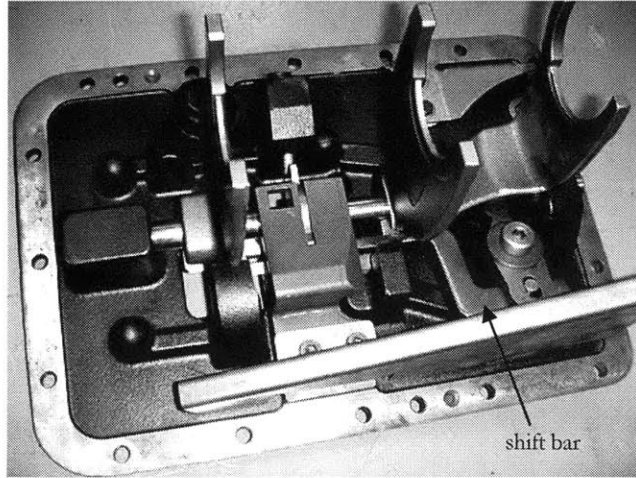


Figure A19: One of three single-rail shift bars

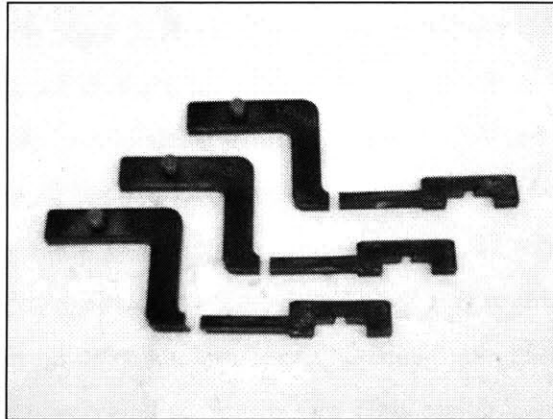


Figure A20: Fracture shift bars 2244-D-1174, shown in Figure A19

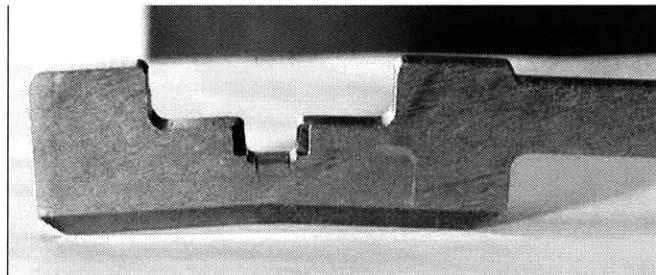


Figure A21: Fractured shift bar 2244-C-1173

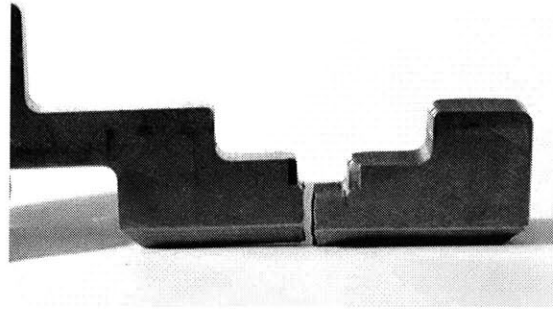


Figure A22: Fractured shift bar 2244-B-1172

As time went on, shift bars continued to fracture (in bending) and OEM frustration continued to mount. ZF Meritor began accepting warranty claims and reacted in 2001 by redesigning the shift bar to increase strength via a larger section size in the fracture location areas, still not fully understanding the root cause of the fractures. Fractures occurred not long after release of the redesigned bars, again due to low cycle bending fatigue, however not in the redesigned area – the fracture location shifted to the next “weakest link” of the bar (Figure A23). Unfortunately, due to dimensional constraints in the new fracture location, this section of the bar could not be increased. The game of “chase the fracture” continued, and the next attempt was to increase the strength of the bar through enhanced heat treatment. The difficulty was how to increase the strength of the bar while maintaining its required flatness and ability to be fine blanked. Promising test results were achieved in late 2001 with prototype bars produced via a material change from SAE 8620 to SAE 1040 (pushing the limits of fine blanking) and a processing change from ferritic nitrocarburizing (which offered no core strength) to a carbo-austempered process (which offered improved core toughness, comparable wear resistance, and minimal distortion). However, before another redesign was carried out, ZF Meritor pulled the plug on the single-rail project, reverting back to the three-rail design.



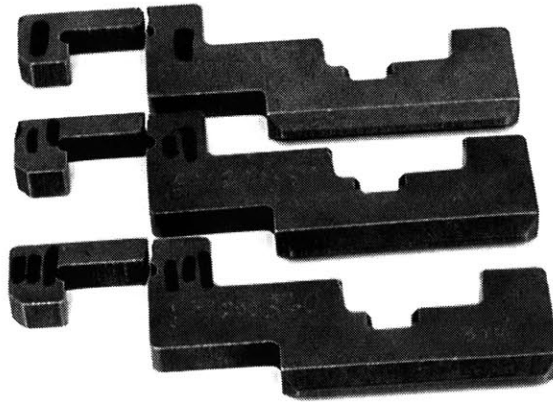


Figure A23: Fractured shift bars after redesign. Redesigned section in tact, but a new weakest-link was exposed.

### *Enhanced Understanding through a Systems Approach*

Today, more than a year after stopping production of the single-rail top-cover, warranty returns continue, however a better understanding of the fracture mechanism has been gained. This understanding has only been possible by taking a holistic view of the transmission system to understand all of the system interfaces involved in the shifting of gears, as well as the emergent, and in this case conflicting, behavior of subsystem interactions. These interfaces include not only physical interfaces (i.e. shift lever, clutch, drive train, etc.) but also information and energy interfaces (i.e. vehicle control units, operator shifting behavior, etc.).

In 2000, the same year that the single-rail design was launched, there was a significant increase in the use of engine control units (ECU) and transmission control units (TCU) in commercial vehicles. It was found that the behavior of these units had a dramatic affect on the shifting behavior of the driver, which in turn affected the stresses placed on the shift bars. When the operator applies pressure to the gas pedal, the ECU relays information to the TCU, which gathers rpm data from the ABS (anti-lock breaking system) brakes to determine the proper gear the operator should be in. While these control systems were designed to optimize the gear selection and engagement process, just the opposite occurs due to the conflict that arises between computer and driver interactions. The conflict stems from the way the control sensors alter the driver's "feel"

of gear engagement. Most experienced drivers rely on shift feel when changing gears. In fact, most don't even use the clutch when shifting. Instead, the drivers will do what is called "feathering the gas" whereby they use the gas pedal to determine the appropriate time to engage the gear based on the feel of the shift lever at the appropriate throttle.

The control units effectively take away the driver's "feel", causing him to try to force the engagement. The more aggressive shifting behavior triggers a chain of events that transfers excessive force through a series of hardware linkages and causes excessive bending stress on the shift bars. This is evidenced by the damaged shift collar splines (Figure A24) caused by the driver trying to engage the collar into a different gear than the one calculated by the TCU. In summary, only by applying systems-thinking, which enabled the expansion of system boundaries beyond merely physical interactions to those that impact functionality through energy and information transfer, such as the ECU, TCU, and ABS control units, is enlightenment of the necessary system level requirements gained.

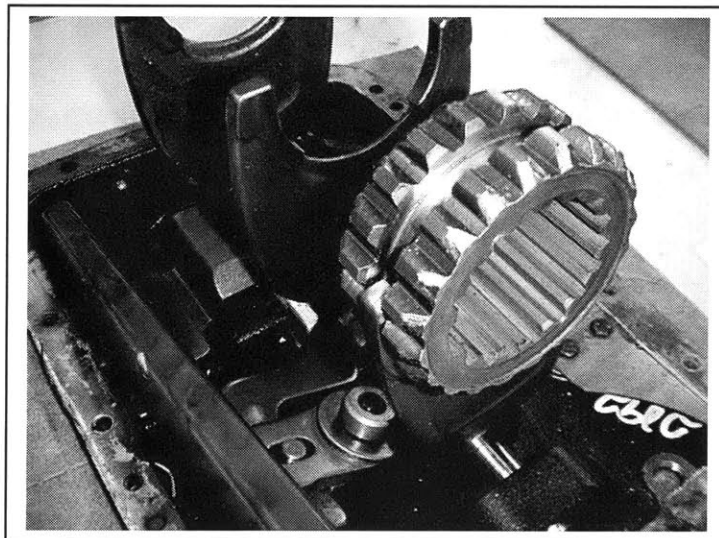


Figure A24: Worn shift collar splines shown on a redesigned single-rail top-cover assembly.

### Case Q4-1: Hydraulic Self-Leveling System

The Self-Leveling system case is short but interesting example of a technology that preceded customer and industry needs, and demonstrates the risk that comes with the pioneer, or first-mover strategy. In the mid-1980's Arvin Industries (now ArvinMeritor) invented and patented a vehicle self-leveling system, which essentially lifted up the vehicle's rear suspension when carrying heavier payloads (see Figure A25). The company invested heavily in its development and tooling, and marketed it under the well-known Gabriel brand. Before long, however, the product was pulled from the market and the tooling was sold off at some meager salvage value.

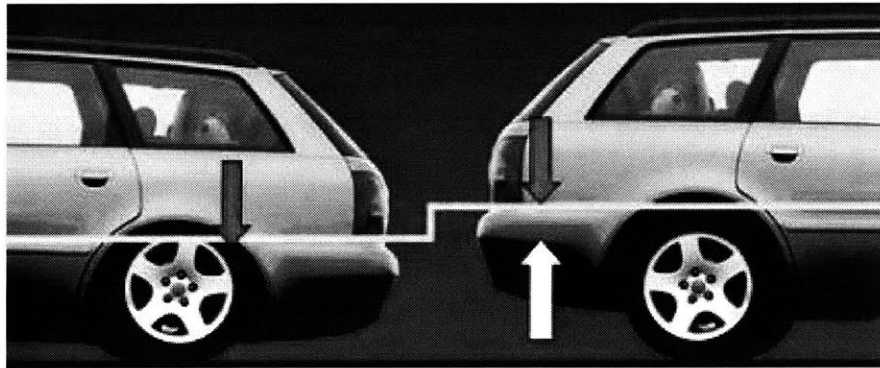


Figure A25: Hydraulic Self-leveling System

On the manufacturing side, the self-leveling system was in need of a very clean environment (in a time pre-dating "clean rooms") and efforts to reach/maintain required cleanliness levels became expensive. On the market side, in a time before SUV's and minivans, heavier loads were predominantly carried by heavier-duty pickup trucks and cargo vans. Arvin's product was targeted toward passenger cars and station wagons, and consumers just didn't see the need for it.

Today there is a substantial market for self-leveling systems, predominantly due to a changing landscape on both the vehicle design and customer need fronts. Passenger car,

minivan, and SUV owners demand the capability of carrying a wide range of payloads, often while towing trailers, boats, campers and the like. In fact, the ratio between payload and vehicle weight is constantly increasing in cars, which acts to reduce both driving safety and comfort. Furthermore, reduced vehicle weight makes it increasingly difficult to tune the suspension system for optimum ride-handling characteristics when such a wide range of payloads are carried. All of these factors, manifested by evolving consumer driving/hauling habits and OEM weight-reduction demands, have made self-leveling systems very attractive.

This case highlights the importance of understanding user habits, and having a balanced focus between the customer and the market. It also underlines the fact that a new technology, alone, does not guarantee profitability. Many aspects of the business model process, such as defining the customer value proposition, and the target market, did not appear to be addressed with this innovation, and consequently value was created but not captured.

## **Case Q4-2: Anti-Squeeze Window Regulator**

### ***Background***

In 1991, ArvinMeritor (formerly Rockwell International) set out to design an innovative concept the Door Systems division referred to as an anti-squeeze window regulator. This regulator would automatically rise without the danger of trapping objects (or body parts) between the glass and door frame. Similar to a one-touch-down control on many automatic windows, where the user can automatically lower the window to the full down position with one touch of a button, the anti-squeeze would enable a one-touch-up feature. The regulator would have the ability to detect objects in the path of the glass while rising, and then back down to avoid harmful contact.

### ***Inward-focused Development***

The Window Regulator division attempted for nearly four years to develop a reliable anti-squeeze regulator, but ultimately realized that they did not contain the internal technical expertise to carry out the design or manufacturing. A contributor to the difficulty was the fact that many of the internal assets involved in developing door components were fragmented into various divisions, such as a motors division, a regulators division, and a newly formed door modules division, with poor communication between the groups. Nevertheless, the electronics expertise, complex algorithms, and sensory technology needed to develop the innovative concept did not exist within the company, and the product was never brought to market.

### ***Project Revival***

In 1996, ArvinMeritor made another attempt at developing an anti-squeeze regulator, this time taking a clean approach and partnering with a company called Temec. Temec was chosen for its reputation as a skilled electronics firm, and for its deep pockets since it was nearly 70% owned by Daimler Chrysler. A large portion of the development was carried out by Temec, who controlled all of the intellectual property that made up the anti-squeeze algorithms. ArvinMeritor was fully dependent on Temec for the product

performance and consequently when the product went to market in 1999, the partnership agreement between ArvinMeritor and Temec left the electronics company with the lion's share of the margins. ArvinMeritor did not meet its profitability target for this product.

### **Case Q4-3: Aluminum Carrier**

#### ***Background***

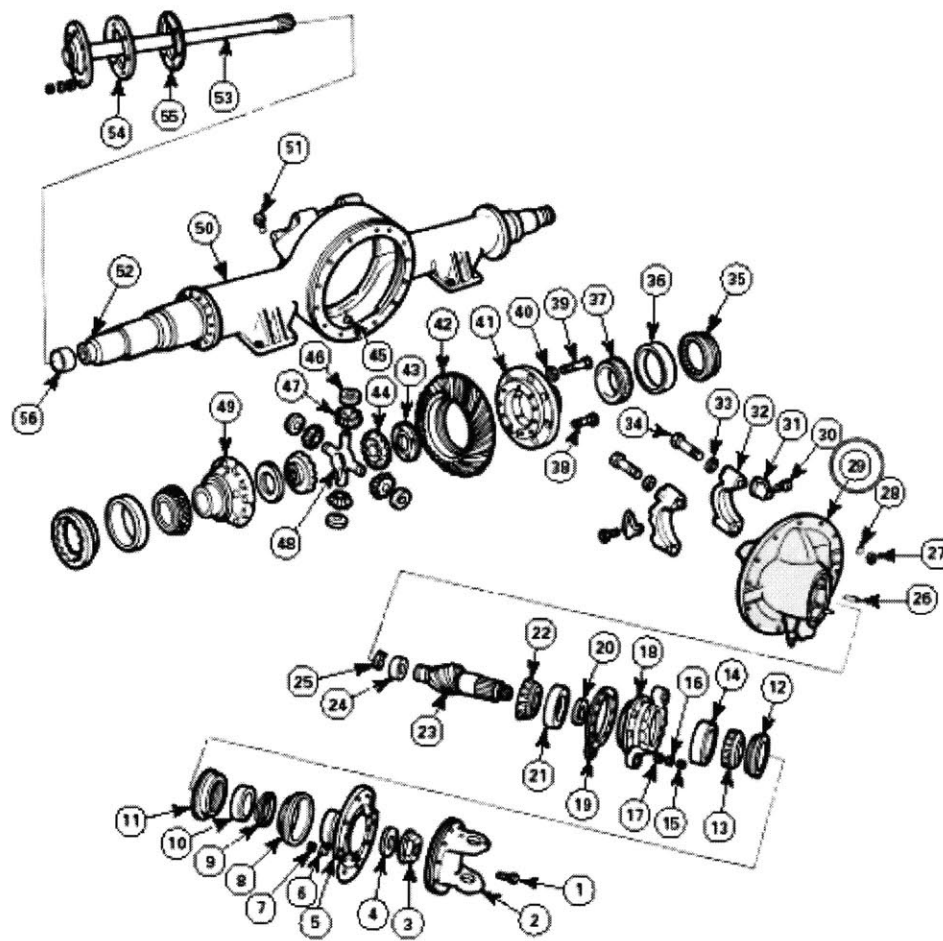
An integral component in the axle assembly is the carrier. The carrier houses a series of gearing components that work together to transfer torque to the axles, which then goes to the wheels, and ultimately to the ground (Figure A26). It also contains the differential components, which enable the inner and outer tires to rotate at different speeds for turning and negotiating challenging road conditions.

#### ***Weight Reduction Initiative***

The carrier is a fairly large component typically cast out of ductile iron, and as OEM cost and weight reduction pressures continued to mount in the 1990's, the component became a prime target for change. In 1995, ArvinMeritor produced a cast aluminum carrier, which offered a combined savings for the forward and rear axle carriers of 90 lbs in comparison with the conventional ductile iron carrier (Figure A27). While the weight savings was substantial, the scalability of the sand casting process limited production capacity. This kept piece price high, and sales low.

In 1999, the project was revived when two OEM's, Volvo and Freightliner, expressed interest in ArvinMeritor's aluminum cast carrier, however only if the price was reduced. These OEM's were hungry for weight reductions to meet their stringent internal axle weight targets, and to gain bragging rights for the "lightest" axle assembly on the market.

ArvinMeritor worked with a supplier to develop a new die-casting process to replace the sand casting that was used previously. Die casting, which incorporated permanent tooling, was much better suited for production capacity and resulted in a manufacturing cost reduction of nearly \$100 per carrier. In addition, ArvinMeritor's sales team persuaded both Volvo and Freightliner to invest in a set of permanent mold die-cast tooling, which significantly reduced ArvinMeritor's up-front costs. Production was to begin in 2000, and ArvinMeritor was ready.



Item	Description	Item	Description	Item	Description
1	Bolt	20	Spacer*	39	Differential Case Capscrew
2	Propeller Shaft Yoke Flange	21	Inner Bearing Cup	40	Washer
3	Pinion Nut	22	Inner Bearing Cone	41	Differential Left-Half Case
4	Washer	23	Drive Pinion	42	Drive Gear
5	Differential Companion Flange	24	Rear Bearing	43	Side Gear Thrust Washer
6	Washer	25	Lock Ring	44	Side Gear
7	Flange Nut	26	Spider Stud	45	Magnetic Drain Plug
8	Dust Wiper	27	Nut	46	Pinion Thrust Washer
9	Oil Seal	28	Washer	47	Differential Side Pinion
10	Oil Seal Wiper	29	Differential Carrier	48	Spider
11	Oil Deflector	30	Lock Bolt	49	Differential Right-Half Case
12	Oil Seal Retainer	31	Adjusting Ring Lock	50	Axle Housing
13	Outer Bearing Cone	32	Bearing Cap	51	Breather
14	Outer Bearing Cup	33	Washer	52	Load Tube
15	Nut	34	Differential Bearing Capscrew	53	Axle Shaft
16	Washer	35	Adjusting Ring	54	Gasket
17	Dowel	36	Differential Bearing Cup	55	Grease Seal, Optional
18	Pinion Cage, Spider	37	Differential Bearing Cone	56	Grease Seal Sleeve, Optional
19	Shim*	38	Drive Gear Capscrew		

Figure A26. Exploded drawing of axle assembly showing the carrier location



### *Unanticipated Consequence Thwarts Profitability*

In anticipation of high volumes, ArvinMeritor's aluminum casting supplier added machining capacity, and had a plan in place for even further increases if needed. High volume pricing was agreed upon by ArvinMeritor and both OEM's, who agreed to make the aluminum carrier a standard part offering. All appeared to be in order, however an unanticipated shift in the marketing strategy of both OEM's as production began, again led to dismal sales.

The aluminum carrier did appear in the standard parts book for both OEM's, however it was unexpectedly (to ArvinMeritor) accompanied by a credit delete option for the end customer. This means that the customer had the option of either selecting the aluminum carrier to attain a substantial weight savings, or electing to take a credit, which reduced the list price of the vehicle by using the conventional heavier ductile iron carrier. When given this choice, most consumers decided that the weight savings gained by selecting the aluminum carrier was less attractive than the cost savings gained by *not* selecting it. Expected volumes for the component never materialized. The bottom line was that although the significant piece price reductions achieved through the permanent mold die-casting process met OEM cost targets, the price was still too high for the end user.

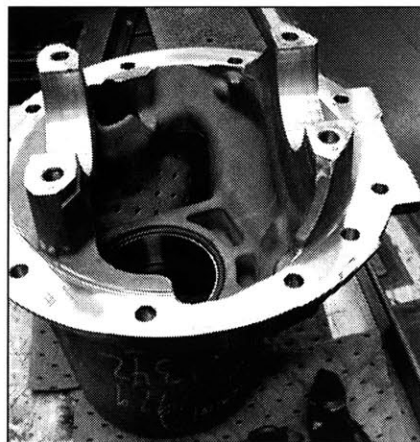


Figure A27. Cast Aluminum Carrier

## Case Q4-4: VST Shock

### *Background*

A shock absorber is a device for reducing the effect of a sudden shock by the dissipation of the shock's energy. On an automobile, springs and shock absorbers are mounted between the wheels and the frame. When the wheels hit a hole or a raised spot on a road, the springs absorb the resultant shock by expanding and contracting. To prevent the springs from shaking the vehicle frame excessively, their motion is restrained by shock absorbers, which are also referred to by their more descriptive term *dampers*. The type of shock absorber found on automobiles is usually a hydraulic type (Figure A28) that has a casing consisting of two tubes, one telescoping into the other. In order for a spring to expand and contract, it must pull apart and push together the ends of this shock absorber. But the ends offer so much resistance that the motion of the spring quickly dies out. The ends are connected to a piston in an oil-filled chamber in the shock absorber's inner tube. The piston can only move if it forces oil past it through valves. This arrangement creates a large resistance to any motion by the piston and consequently by the ends.

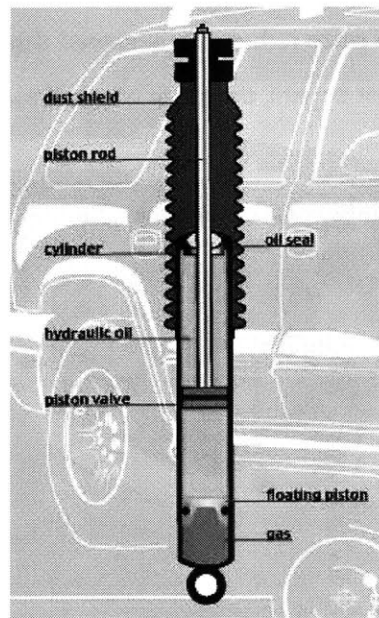


Figure A28: Schematic of the inside of a shock absorber

The effective movement of oil through the shock absorber valves significantly affects the vehicle's ride harshness. In the early 1990's, Arvin Industry's Motion Control division created a new and inexpensive valve design that was found to significantly decrease ride harshness at various vehicle speeds. This valve design was targeted for aftermarket shocks for the US market. Development was carried out and the product was launched with significant success in the United States; drivers could definitely "feel" the difference – and loved it.

### *The Technology*

The new valve design, called the velocity sensing technology (VST) shock, was an elegant innovation in terms of its simplicity and low cost. The design simply consisted of a flat and thin high-strength steel washer that sat on the top of the valve mechanism. As shown in Figure A29, a small gap existed between the valve mechanism surface and the washer, allowing oil to pass between the two objects at low piston actuation speeds (i.e. low oil chamber pressure), and then through the valving mechanism. This resulted in a noticeably smoother ride. At high piston actuation speeds, significant pressure is built up in the chamber and the force exerted on the washer is enough to cause the ends to bend downward and make contact with the valve mechanism, thereby sealing off the path of oil flow to the valve holes (Figure A30). Under these conditions, the mechanism behaved like a normal shock absorber (Figures A31 & A32).

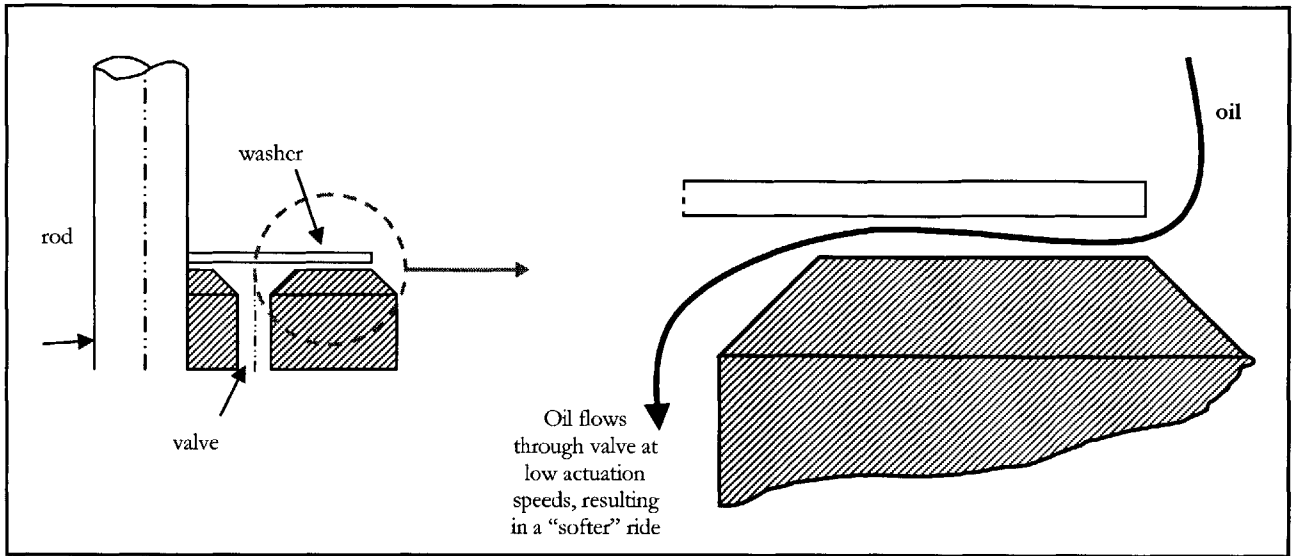


Figure A29: VST valve mechanism at low shock rod actuation speeds

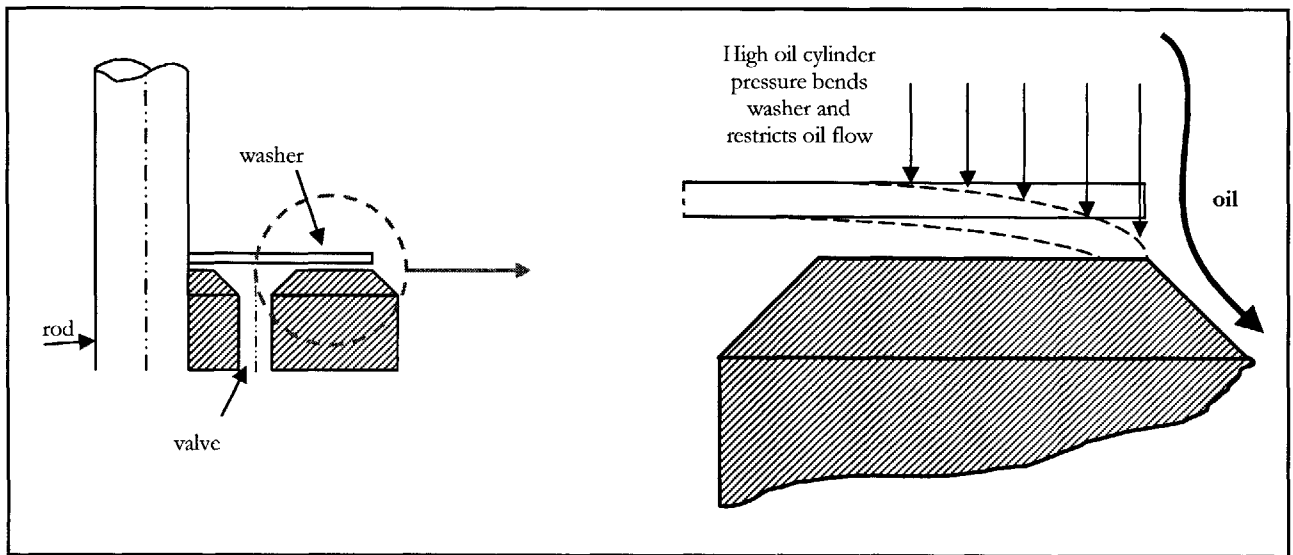


Figure A30: VST valve mechanism at high shock rod actuation speeds

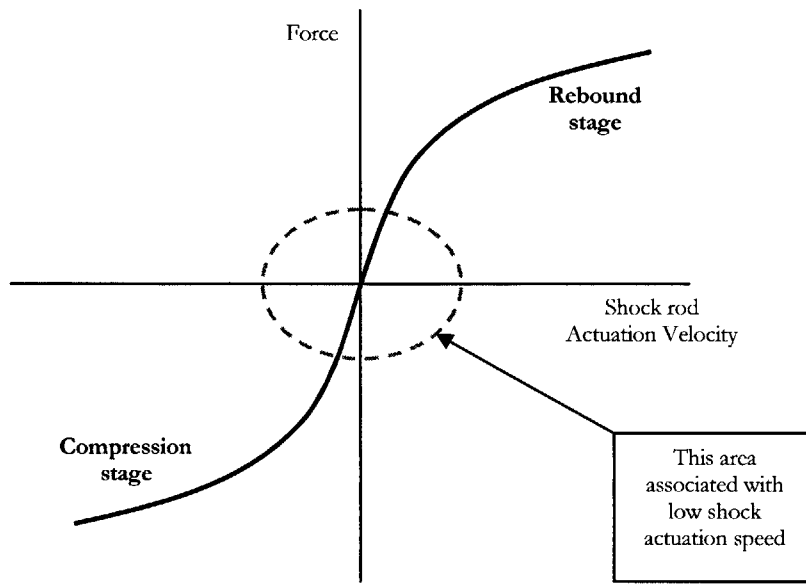


Figure A31: Force-Velocity curve for a typical shock

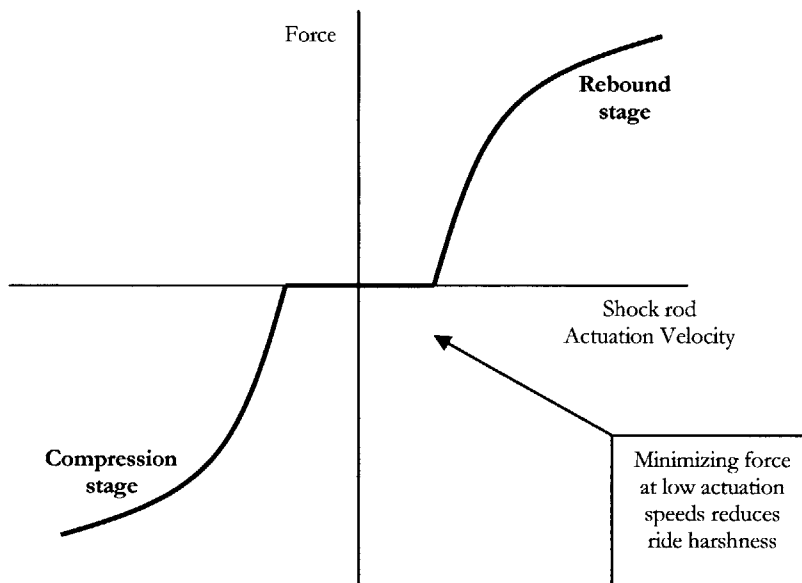


Figure A32: Force-Velocity curve for a VST shock

### ***A Failed European Launch***

Springboarding off of the success in the US market, the VST shock was launched in Europe, however resulting in a very different outcome – sales in Europe were almost nonexistent. The reasons for this dismal market performance become evident when analyzing the driver habits and needs of the United States and European markets.

The US culture is not at all accommodating to the aggressive driver, as speed limits and road conservatism are relatively strictly enforced, and US highways and surface streets are becoming increasingly overcrowded. Therefore, the average US driver is looking for comfort and convenience in getting from point A to point B. This need is met with the VST shock because drivers realize the advantages of the technology, i.e. the more comfortable ride “feel”, but do not encounter the technology’s disadvantages, which include the slightly less steerability, traction, and braking reaction forces that are realized when attempting to push the car to its limits.

The majority of Europeans, however, take their driving much more seriously. These drivers are much more aggressive than the typical US driver, and tend to accelerate to relatively high speeds in short stretches of road and around corners. In addition, European roads, on average, are less crowded, and driving laws are much less enforced. As one European driver stated, “Europeans enjoy the *driving experience*. We take pride in knowing how to push our cars to the limit. You will not find many automatic transmissions in our cars – and you will not see cup holders...cars are not for eating and drinking in, they are for driving!” The same driver test drove a vehicle equipped with the VST shock, and did not like it. He did not see the softer ride as an advantage because he could not “feel” how the car was handling the road, but he did encounter the technology’s disadvantages, and felt that the delayed reaction time, especially in the steering sensitivity around curves at high speeds, was dangerous.

This case demonstrates that identifying and understanding customer needs are critical aspects for a successful innovation. Another lesson learned was that cultural impacts on profitability can be devastating if the upstream marketing analyses are not adequately conducted. Furthermore, in order to create a sound value proposition, and a business model that captures value for the firm, customer needs must be accurately addressed.

## APPENDIX B

Factor	Description
<b>Up-Front Planning</b>	
Identification of Customer Needs	Understanding the customers and their needs, wants, desires, etc. What makes this difficult is that customers may or may not be able to articulate their needs. The most benefit often comes from addressing the “unspoken needs”, resulting in customer delight.
Idea Generation, Selection, Protection	The processes used by the firm to generate innovative ideas and concepts, the filtering mechanisms used to determine which concepts to produce, and the protection of these ideas through patents, trade secrets, etc.
Customer vs. Market Focus	An unbalanced focus on either the customer or the market can lead to the development of a product that nobody wants. A balanced understanding of customer needs and market drivers places the firm in a desirable position for growth and profitability.
<b>Non-Product Related</b>	
Depth of Customer Relationship	Building strong customer relationships means identifying, attracting, and retaining your customers, and can lead to long-term profitability. Often the primary differentiator between a firm and its competition is the strength of that firm’s relationship with its customers.
Customer Service/Technical Support	The quality of customer service and the capability of the firm to offer competent and responsive problem solving and technical support often play an important role in a product’s success. In addition, the service after the sale is a key factor in gaining or losing repeat business.
Product Availability	This refers to the ability of the firm to make its products available to potential customers. It may mean availability in the sense of delivering the product to a geographical location, or perhaps the ability to develop a product architecture that is compatible with a customers existing technology.



Sales Force	Refers to the size of sales force, its experience, qualifications, and assertiveness, and the ability to effectively introduce new products in a way that secures customer contracts.
Marketing	The extent to which the Marketing department influenced the profitability of the product/innovation through accurate identification of customer needs, and the areas of price, promotion, distribution, and input to product design.
Technology Clockspeed	Clockspeed, a term dubbed by Charlie Fine, refers to the rate at which something evolves, such as a company, an industry, or in this context, a product technology. Understanding the clockspeed of the technology used in a particular industry may be very important, and can affect the firm's technology selection, product development process, and time-to-market.
Scalability	The ability of the firm to produce product quantities that satisfy market demand, and the flexibility to grow production to meet potential future demand increase.
<b>Customer Perception</b>	
Highly Visible Benefits	Product/Process/Service attributes or benefits that are <i>very obvious</i> to the customer.
Useful Benefits	Product/Process/Service attributes or benefits that are easily perceived by the customer as being <i>useful</i> .
Price per Performance Characteristics	The lower the ratio of price to performance, the higher the customer's satisfaction and value perception
Supplier Image	In an industry as competitive as the automotive supply industry, a supplier's image can have a dramatic affect on the profitability of its new products. In fact, if two competitors were to launch new competing products simultaneously, the OEM may choose the supplier with the better image, even if its competitor's product is superior.
OEM Image	Since the products manufactured by the supplier are represented in the OEM's vehicle, the consumer's perception of the OEM is important. The supplier's profitability is often dependent on the success of the OEM final product.

<b>Product/Process/Service Differentiation</b>	
Technology	The extent to which the technology alone contributed to the product's profitability (or lack thereof).
Functionality	The extent to which the product satisfied customer expectations in terms of carrying out its intended purpose.
Distribution	The strategy used to deliver the product to the customer.
Technology "Readiness"	Refers to the extent to which a technology is mature enough to successfully and sustainably carry out its intended function. Technology readiness also refers to the extent to which the targeted market perceives the technology to be useful and desirable.
<b>Product Development</b>	
Internal Technical Competence	The extent to which the internal expertise of the firm's personnel contributed to the successful development and profitability of a new product design.
Enterprise Collaboration	The extent to which members of the supply chain worked together to design and develop the product, and the effect of this collaboration on product success.
Partnerships/Alliances/JV's, etc.	The effect that partnership agreements and strategies had on product success.
<b>Customer Switching Costs</b>	
Training Costs	The cost associated with teaching an employee a new task, process, or system. It may also refer to the cost savings from not having to train the employee if the task is no longer needed or is outsourced.
Price	The extent to which product price affected its market success.
Maintenance Costs	Costs associated with providing upkeep of the product
Operating Costs	The extent to which the product affects the costs of operating the customer production or assembly facility, including cost of running machinery, assembly, overhead, training, etc.

Disposal Costs	Costs associated with removing, destroying, or recycling the product at the end of its life cycle.
Implementation Costs	Refers not only to the cost of acquiring a product and putting it to use, but also the fabrication or modification of existing equipment that may be necessary to achieve the new product's intended functionality.
Cost of Non-Quality	Costs associated with manufacturing rework, scrap, recalls, warranty campaigns, etc.
<b>Business Model</b>	
Value Proposition	The value created for users by the offering based on the technology
Value Chain	The structure required to create and distribute the offering, and to determine the complementary assets needed to support the firm's position in this chain
Value Network	The linking of suppliers and customers, including identification of potential complementary firms and competitors
Market Segment	The users to whom the technology is useful and the purpose for which it will be used
Cost Structure / Target Margins	To specify the revenue generation mechanism(s) for the firm, and estimate the <i>cost structure</i> and <i>target margins</i> of producing the offering, given the value proposition and value chain structure chosen
Competitive Strategy	The way by which the innovating firm will gain and hold advantage over rivals

## APPENDIX C

### **STEP-BY-STEP Through the Lead User Process**

*The following was excerpted from "Creating Breakthroughs at 3M", by Eric von Hippel, Stefan Thomke, and Mary Sonnack.*

The lead user process gets under way when a cross-disciplinary team is formed. Teams typically are composed of four to six people from marketing and technical departments; one member serves as project leader. Team members usually will spend 12 to 15 hours per week on the project for its duration. That high level of immersion fosters creative thought and sustains the project's momentum.

Lead user projects proceed through four phases. The length of each phase can vary quite a bit; the *3M* team spent six months alone on phase 3, when it researched surgical conditions in developing countries through on-site visits. For planning purposes, a team should figure on four to six weeks for each phase and four to six months for the entire project.

**Phase 1:** Laying the foundation. During this initial period, the team identifies the markets it wants to target and the type and level of innovations desired by key stakeholders within the company. If the team's ultimate recommendations are to be credibly received, these stakeholders must be on board early.

**Phase 2:** Determining the trends. It's an axiom of the process that lead users are ahead of the trend. But what is the trend? To find out, the team must talk to experts in the field they are exploring people who have a broad view of emerging technologies and leading-edge applications in the area being studied.

**Phase 3:** Identifying lead users. The team now begins a networking process to identify and learn from users at the leading edge of the target market and related markets. The group's members gather information that will help them identify especially promising innovations and ideas that might contribute to the development of breakthrough products. Based on what they learn, teams also begin to shape preliminary product ideas and to assess the business potential of these concepts and how they fit with company interests.

**Phase 4:** Developing the breakthroughs. The goal is to move the preliminary concepts toward completion. The team begins this phase by hosting a workshop with several lead users, a half-dozen in-house marketing and technical people, and the lead user team itself. Such workshops may last two or three days. During that time, the participants first work in small groups and then as a whole to design final concepts that precisely fit the company's needs.

After the workshop, the project team further hones the concepts, determines whether they fit the needs of target market users, and eventually presents its recommendations to senior managers. By that point, its proposals will be supported by solid evidence that explains why customers would be willing to pay for the new products. Although the project team may now disband, at least one member should stay involved with any concepts that are chosen for commercialization. In that way, the rich body of knowledge that was collected during the process remains useful as the product or service families are developed and marketed.

# Crawley System Architecture Framework

## Architecture & Business Case Linkage

